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OFFICE REPORT JANUARY 1979

KERN RIVER BASIN
California

HYDROLOGY

DEPARTMENT OF THE ARMY
Sacramento District, Corps of Engineers
Sacramento, California

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HYDROLOGY OFFICE REPORT
KERN RIVER, CALIFORNIA

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CHAPTER I
INTRODUCTION

1. PURPOSE AND SCOPE. - This office report has been prepared to present basic hydrologic data and criteria for use in feasibility studies for possible water resources development in the Kern River Basin. This report discusses the hydrologic characteristics of the area, presents an analysis of flow-frequencies, reservoir sedimentation, and freeboard requirements, and describes the development of standard project and probable maximum floods resulting from winter-type rain storms. An analysis of spring snowmelt floods is not required for this study. The primary emphasis in this report is on the Kern River at Isabella Lake; however, basic criteria is presented that could be used to develop hydrologic data for other locations in the basin.

CHAPTER II
DESCRIPTIVE HYDROLOGY

2. DESCRIPTION OF BASIN. -

a. General. - The Kern River basin lies in Kern and Tulare Counties at the southern end of the San Joaquin Valley. The general location and features of the basin are shown on chart 1.

The basin above Isabella Lake is about 90 miles long and 30 miles wide, has an elliptical shape with the long axis running north and south, and has a drainage area of 2074 square miles. The basin is bounded by the Kings River basin on the north, the Poso Creek Stream Group and Kaweah and Tule River basins on the west, the Caliente Creek basin on the south, and the Owens Lake basin on the east. Elevations in the basin above Isabella Lake range from about 2500 feet to over 14,000 feet at Mount Whitney. About 80 percent of the basin is above the 5000-foot level. A topography map is shown on chart 2. Area-elevation curves are shown on chart 3. The Tehachapi Range to the south and both the Coast Range and the Greenhorn Mountains to the west partially shield the basin from storms originating over the Pacific Ocean. A high mountain ridge separates the basin into eastern and western watersheds. The western watershed is drained by the main Kern River (referred to as the North Fork) while the eastern watershed is drained by the South Fork. The North Fork basin is among the most rugged of the Sierra Nevada basins and is characterized by granite peaks and ridges and deep precipitous canyons. Numerous small glacial lakes form the headwaters of the tributary streams. The South Fork basin lies east of and drains a high but less rugged region that the North Fork. Mountainuous slopes are less abrupt, stream gradients are flatter, and canyons are relatively shallow. The South Fork itself consists of a series of long meadows separated by short reaches of steep canyons. The southern and southeastern portions of the South Fork basin are desert-like in character with lower mountains well-worn by erosion.

Below Isabella Lake the Kern River flows southwesterly for about 33 miles in a deep and rugged canyon and emerges onto the valley floor about 16 miles upstream of Bakersfield. Below the canyon mouth the river flows southwesterly along a low alluvial ridge, past Bakersfield and Oildale, to Buena Vista Lake. At Buena Vista Lake the river turns and flows northeasterly to Tulare Lake. Between the canyon mouth and Tulare Lake there are numerous diversions for irrigation. In all but years of exceptionally large runoff all of Kern River water is either stored in Isabella Lake, used for irrigation, or used to recharge the groundwater basin. In years when excess water potentially damaging to Tulare Lake occurs, all or a portion of it can be diverted to the California Aqueduct via the Kern River - California Aqueduct Intertie.

Both Buena Vista and Tulare lakebeds are broad, flat, closed depressions with no outlets to the ocean. Tulare lake is the common terminus of the Kings, Kaweah, Tule, and Kern Rivers. The lakebeds are normally farmed intensively but are used, on occasion, for the storage of excess flood waters.

b. Soils and vegetation. - The North Fork basin above an elevation of about 10,000 feet has a very small amount of soil and vegetative cover and contains broad expanses of exposed rock on the mountain ridges and peaks. The area below 10,000 feet has a moderate to deep soil cover, some areas of wild grasses, areas of scattered coniferous and deciduous trees, and large areas of brush. The South Fork basin has a deeper soil cover and a lighter vegetative cover when compared to the North Fork. Brush and low foothill conifers are predominate. A study of vegetative cover maps prepared by the U.S. Forest Service indicates the following vegetative cover over the entire basin:

	Range of elevation (ft)	Percent of basin area
Grassland (with scattered timber)	(2,500-3,000) (8,000-9,000)	5
Brushland (chapparral, etc.)	(2,500-6,000)	28
Deciduous forest	(4,000-6,000)	7
Light coniferous forest (20-50% cover)	(6,000-9,000)	22
Heavy coniferous forest (over 50% cover)	(7,000-7,500)	Negligible
Sub-alpine timber (juniper, lodge pole pine, etc.)	(9,000-12,000)	9
Open ground (barren, and lakes)	(2,500-5,000) (11,000-14,000)	12
Foothill conifers	(4,000-7,000)	17

3. EXISTING WATER RESOURCE DEVELOPMENT. - The water resources of the Kern River basin have been developed to a substantial level for hydroelectric power, irrigation, flood control, and recreation purposes.

The Isabella Lake project is the most significant development in the basin. It consists of a dam and 570,000 acre-foot lake, constructed by the Corps of Engineers and completed in 1953, that is operated primarily for flood control, conservation, and power release regulation. The lake, together with channel improvements on the valley floor along the Kern River and in the Buena Vista Lake area, provides flood protection to agricultural lands, oil fields, and the cities of Bakersfield and Oildale. Numerous dikes and levees have been built in the Buena Vista and Tulare lakebeds to form areas for storage of excess water, thus providing additional flood protection and irrigation storage for reclaimed agricultural lands in the former lake bottoms. The Kern River - California Aqueduct Intertie is located in the vicinity of Buena Vista Lake, about 20 miles southwest of Bakerfield. This project was completed by the Corps of Engineers in 1977 and provides flood protection to the Tulare lakebed by diverting excess Kern River snowmelt water into the California Aqueduct for beneficial use.

Four privately-owned hydroelectric generating plants are located in the Kern River basin as indicated on chart 1. All of the plants have been licensed by the Federal Power Commission. Data for the plants are summarized in the tabulation below.

Existing Hydroelectric Powerplants
Kern River Basin

Plant Name	Drainage Area (sq mi)	Gross Head (ft)	Installed Capacity (kw)	Annual Average Generation (million kwh)	Year Installed	Operating Agency 2/
Kern Canyon	2,310	260	8,480	47.2	1921	PG&E
Kern No. 1	2,273	877	16,000	173.2	1907	S.C.E.
Borel	1,038 3/	1/	9,200	64.0	1904	S.C.E.
Kern No. 3	852	821	32,000	197.5	1921	S.C.E.

1/ Gross head for each of three units is 255, 258 and 265 feet, respectively.
2/ PG&E = Pacific Gas and Electric Company
S.C.E. = Southern California Edison Company
3/ Uses only water diverted from North Fork Kern River.

There are many locally constructed works for irrigation in the basin. Several minor diversions are located in the valley of the South Fork above Isabella Lake. Below the Kern Canyon powerplant there are numerous diversion, canals, and distribution ditches. The Friant-Kern Canal, a portion of the Central Valley Project of the U.S. Bureau of Reclamation, is utilized to divert water stored in San Joaquin basin reservoirs southward for use in Fresno, Kings, Tulare and Kern Counties. The canal terminates near Bakersfield. The California Aqueduct of the State Water Project, constructed jointly by the state and the federal governments, delivers water to water service agencies in Kern County. The aqueduct, shown on chart 1, conveys water from the Sacramento-San Joaquin Delta to the San Luis Reservoir and thence south.

4. <u>CLIMATE</u>. - The Kern River basin has a temperate climate ranging from semiarid at the lower elevations to mountain-type in the higher elevations. The lower elevations have cool, wet winters and hot, dry summers, while the upper elevations have relatively short, mild summers and long, severe winters.

Normal annual precipitation varies from 7 inches near Bakersfield to about 55 inches in the headwaters. A normal annual precipitation isohyetal map is shown on chart 4. Normal annual precipitation for different segments of the basin is indicated in the following tabulation.

Segment of Basin	:Normal Annual Precipitation (inches)
Buena Vista Lake	5.0
Tulare Lake	6.5
Foothill area below Isabella Lake	14.7
North Fork Kern River above Isabella Lake	28.4
South Fork Kern River above Isabella Lake	16.7

About 90 percent of the runoff-producing precipitation occurs during the period November through April. On the valley floor almost all of the precipitation occurs as rain, while in the mountains it occurs as rain in the summer and rain or snow during the other seasons. Winter storms usually produce rain at the lower elevations (below 5,000 feet) and snow at the higher elevations. The monthly distribution of precipitation at several stations in and near the basin is illustrated in the following tabulation.

Average Annual Precipitation
(inches)

Month	Bakersfield WBAP 1/ (elev. 495) Amount	%	Isabella Dam 2/ (elev. 2660) Amount	%	Kern PH #3 3/ (elev. 2703) Amount	%	Posey 3E 4/ (elev. 4920) Amount	%
Jul	0.02	0.3	0.09	0.9	0.10	0.9	.03	0.1
Aug	0.01	0.2	0.22	2.1	0.19	1.6	.22	0.8
Sep	0.08	1.4	0.44	4.2	0.27	2.3	.58	2.0
Oct	0.26	4.6	0.30	2.9	0.28	2.4	1.20	4.2
Nov	0.69	12.1	1.15	11.0	1.33	11.4	3.04	10.6
Dec	0.74	12.9	1.89	18.1	1.78	15.2	4.82	16.7
Jan	0.96	16.8	2.07	19.8	2.74	23.5	5.22	18.1
Feb	1.03	18.0	1.73	16.6	1.88	16.1	4.28	14.9
Mar	0.83	14.5	1.23	11.8	1.66	14.2	3.96	13.8
Apr	0.85	14.9	0.93	8.9	1.15	9.9	3.90	13.5
May	0.19	3.3	0.28	2.7	0.22	1.9	1.22	4.2
Jun	0.06	1.0	0.10	1.0	0.07	0.6	.31	1.1
Total	5.72	100.0	10.43	100.0	11.67	100.0	28.78	100.0

1/ Climatological normal for 1941-1970
2/ Average for 1954-1976
3/ Average for 1947-1976
4/ Average for 1955-1976

The snow pack at the higher elevations accumulates during the winter months until about the first of April when increased temperatures cause the pack to begin melting. Snow pack data typical of that for wet (1969), normal (1965), and below-normal (1977) years are illustrated in the following tabulation.

1 April Snow Pack Data
Kern River Basin

Snow Course	Elev. in ft	Snow Depth in inches 1969	1965	1977	Water Content (inches) 1969	1965	1977	Average 1/ 1931-55	% of Average 1969	1965	1977
Bighorn Plateau	11,350	123.7	65.6	17.4	55.3	25.8	5.0	23.0	240	112	22
Big Whitney Meadow	9,750	102.4	44.0	18.6	45.0	13.7	4.9	17.0	265	81	29
Guyot Flat	10,650	117.5	50.9	18.8	50.6	18.0	4.8	21.0	241	86	23
Bonita Meadows	8,300	115.5	23.0	6.9	50.2	10.3	3.6	14.0	359	74	26

1/ Average values of 1 April water content are averages for 45-year period (1931-1975) from Snow Survey Data, California Cooperative Snow Surveys, 1977.

Temperatures in the basin range from hot on the valley floor during the summertime to below zero readings at the higher elevations during the winter. Observed temperature extremes are 120° and 15°F on the valley floor, 118° and 13°F at Bakersfield, 112° and 11°F at Isabella Dam and 109° and 11°F at Kern River P.H. #3 above Kernville. The monthly distribution of mean temperatures for key stations in and near the basin is illustrated in the following tabulation.

Average Monthly Temperature (°F)

Month	Bakersfield WBAP1/ (Elev. 495)	Kern P.H. #32/ (Elev. 2703)	Isabella Dam3/ (Elev. 2660)	Posey 3E4/ (Elev. 4920)
Jan	47.5	44.8	43.8	37.9
Feb	52.4	48.4	47.1	39.4
Mar	56.6	51.6	50.0	41.1
Apr	62.7	57.8	54.4	43.8
May	69.8	65.6	63.3	51.8
Jun	76.9	73.8	72.5	59.5
Jul	83.9	81.2	79.6	67.0
Aug	81.6	79.4	78.0	66.5
Sep	76.6	74.5	72.0	62.0
Oct	66.9	63.5	61.8	53.7
Nov	56.0	52.6	51.2	45.5
Dec	47.9	45.9	44.6	39.3
Mean	64.9	61.6	59.9	50.6

1/ Climatological normal for 1941-1970
2/ Average for 1947-1976
3/ Average for 1955-1976
4/ Average for 1955-1976

5. STREAMFLOW. - Streamflow records in the Kern River basin are available at the following locations. Locations are shown on chart 1.

Station	Drainage Area (sq mi)	Approx Stream-Bed Elev. (ft)	Period of Record (yrs)
Golden Trout Creek near Cartago	23.6	8,940	Oct 56-Sep 67, Apr-Sep 69, 70, 72-76 1/
Kern River near Quaking Aspen Camp	530	4,690	Oct 60-Sep 74, 75-76 1/
Little Kern River near Quaking Aspen Camp	132	4,680	Aug 57-Sep 68, Apr-Sep 69, 70, 72-76 1/
Kern River near Kernville	846	3,620	Jan 12-date
Kern River at Kernville	1,009	2,630	Jan 05-Dec 12, Oct 53-date
South Fork Kern River near Olancha	146	7,840	Oct 56-Sep 67, Apr-Sep 69, 70, 73-76 1/
South Fork Kern River near Onyx	530	2,900	Sep 11-Aug 14, Jan 19-Sep 42, Oct 47-date
Kelso Creek near Weldon	101	3,180	Aug 58-Dec 66
Kelso Creek near Weldon	163	2,790	Jul 75-date 1/
South Fork Kern River at Isabella (inundated by Lake Isabella)	983	2,480	Oct 10-Sep 13, Jan 29-Sep 52
Isabella Lake near Isabella	2,074	2,435	Oct 53-date
Kern River below Isabella	2,074	2,435	Apr 45-date
Kern River near Democrat Springs	2,258	1,840	Jul 50-date
Kern River near Bakersfield	2,407	450	Oct 1893-date

1/ Crest stage gage for period indicated

The average annual inflow to Isabella Lake is 614,000 acre-feet (based on records from 1946 through 1977). About 85 percent of this inflow originates in the North Fork basin. The average annual flow at Bakersfield is 691,000 acre-feet. (This figure represents unregulated condition flows and is based on the record from 1894 through 1975; the record since 1953 was adjusted to account for the operation of Isabella Lake.) About two-thirds of the annual runoff from the Kern River basin occurs from snowmelt during the April through July period. The seasonal and areal variation of runoff is illustrated in the following table.

Average Monthly Runoff

	Kern River near Kernville		South Fork Kern River near Onyx	
Month	Acre-feet	%	Acre-feet	%
Oct	14,100	2.7	1,300	1.6
Nov	15,700	3.0	1,900	2.3
Dec	20,400	3.9	3,700	4.5
Jan	19,400	3.7	3,600	4.4
Feb	25,600	4.9	4,800	5.8
Mar	35,600	6.8	8,300	10.0
Apr	64,900	12.4	19,600	23.7
May	114,500	21.9	25,200	30.5
Jun	117,200	22.4	9,200	11.1
Jul	57,000	10.9	2,700	3.3
Aug	24,100	4.6	1,300	1.6
Sep	14,600	2.8	1,000	1.2
Total	523,100	100.0	82,600	100.0

6. STORM CHARACTERISTICS. - Major flood-producing storms over central California are generally associated with storm systems that originate over the Pacific Ocean at about 30° to 50° north latitude. As these systems approach the coast the trajectory is over cooler water, thus retarding release of moisture until the air mass is borne inland where the north-south coast ranges lift the air mass and cause condensation and release of moisture. Precipitation in the Kern River basin is largely orographic in nature and usually results from air masses that approach the basin from the northwest, west, or southwest. Because of its location behind two barrier ridges and its orientation, the basin above Isabella is more sheltered and is less likely to receive large amounts of precipitation than any other major Sierra Nevada river basins. The South Fork has the least opportunity to receive precipitation from Pacific storms as it lies behind not only the Coast, Tehachapi, and Greenhorn Mountain ranges, but also behind the high ridge separating the two forks of the Kern River. This characteristic is evident from a comparison of storm amounts produced by two of the largest storms in recent history.

Basin	Average Basin Precipitation (inches)[1/] 2-6 December 1966	24-26 January 1969
North Fork	20.8	9.9
South Fork	12.3	5.3

1/ Precipitation values estimated from storm isohyetal maps, charts 6 and 7.

7. FLOOD CHARACTERISTICS. - Flood flows on the Kern River are of two major types: winter rainfloods and spring snowmelt floods. In addition, cloudbursts can produce relatively large flows from small areas.

Winter rainfloods generally occur during the period November through March and are caused by large general rain storms augmented at times by the melting of snow at the intermediate elevations. These winter floods have short, high peaks and are generally of short duration and comparatively small volume. The intensity of runoff is dependent to a substantial degree on the location of the snowpack in the basin. It is not uncommon for the basin to be relatively snow-free up to the 9,000 to 10,000 foot elevation during December and even January, but such a condition becomes very unlikely as the season progresses into February and March. Further, a high snow-line usually implies light antecedent precipitation with a resultant dry condition not conducive to maximum runoff. Conversely, wet antecendent conditions usually produce an accummulation of snow over the higher portion of the basin which is sufficient to inhibit run-off from that area so that only the lower part of the basin can contribute to flood flows. An example of the variation in contributing area is evident from an examination of the December 1966 and January 1969 floods. Available data indicates that the contributing area for the December 1966 flood was below the 8500-foot elevation and for the January 1969 flood was below the 7000-foot elevation.

The largest rainflood of record in the Kern River basin occurred on 6 December 1966 and had an estimated peak inflow to Isabella lake of 120,000 cfs and a 5-day volume of 230,000 acre-feet. The peak flow at Bakersfield was about 9300 cfs and the maximum release from Isabella during the peak was about 430 cfs. A large flood also occurred in December 1867 but detailed information about this event is not documented. Runoff data at several locations for three recent rainfloods is presented in the following table.

Location	23-27 December 1955 Peak (cfs)	Vol (af)	5-9 December 1966 Peak (cfs)	Vol (af)	24-28 January 1969 Peak (cfs)	Vol (af)
Kern River at Kernville	29,400	63,500	74,000	159,000	26,900	70,200
South Fork Kern River near Onyx	2,050	6,600	28,700	43,600	9,200	17,700
Inflow to Isabella Lake	23,000	59,800	120,000	230,000	35,000	97,400
Isabella Releases 1/	N.A. 2/	5,500	N.A.	3,500	N.A.	8,000
Kern River near Democrat Springs	N.A.	5,700	10,100	15,200	2,920	14,900
Kern River near Bakersfield	N.A.	5,300	9,290	16,000	N.A.	20,300

1/ Includes releases to Borel Canal
2/ Not available

Snowmelt floods have moderate peak flows but very large volumes extending over a two-to-four-month period from April through July. During the large snowmelt floods the North Fork produces about 80 percent of the total runoff into Isabella Lake. the largest snowmelt flood of record occurred in 1969 when inflow to the lake was 1,657,000 acre-feet during the April through July period.

Cloudburst floods are characterized by very high peak flows of short duration and low volume. These type floods usually occur during the summer or fall and result from cloudburst-type storms. Inflows into Isabella Lake are not influenced by cloudbursts due to their small areal coverage. The largest cloudburst flood of record in the Kern River basin occurred on 29 September 1976 and produced a peak flow of 11,000 cfs from Kelso Creek (drainage area at gage is 163 square miles).

CHAPTER III
STORM ANALYSIS

8. GENERAL. - For purposes of hydrologic analysis the Kern River basin has been subdivided as indicated on chart 5. These subdivisions were made at the various stream gage locations to facilitate analysis of past floods. A flow routing diagram is shown on chart 8. Two storm periods, December 1966 and January 1969, were selected for analysis. The analysis was made by developing a mathematical model of the basin using the computer program "HEC-1, Flood Hydrograph Package," as modified by the Sacramento District. The analysis includes a determination of base flows, loss rates, unit hydrographs, and flood routing parameters. Hydrographs of the floods analyzed along with computed reconstitutions are shown on chart 11.

9. STORM PRECIPITATION. - Basin precipitation was determined from the isohyetal maps, charts, 6 and 7. These maps were prepared from precipitation data at the stations indicated on the charts. Time distribution of precipitation was based on the records at one or more of the recording precipitation stations.

10. SNOW EFFECTS. - Available temperature data and observations in the basin before and after the storm periods analyzed indicated that precipitation fell as snow above the 8500-foot elevation during the December 1966 storm and above the 7000-foot elevation during the January 1969 storm. Accordingly, only precipitation below these elevations was considered in determining basin mean precipitation. Insufficient data is available to complete a snowmelt analysis. From the limited data available it was evident that very little snow was present on the basin below the above elevations prior to the storms analyzed and that snowmelt produced by the storms was very minor. Accordingly, a snowmelt analysis was not made.

11. BASEFLOW. - Baseflow was separated from the total runoff hydrograph as indicated on chart 11. Baseflow adopted for standard project and probable maximum flood computations was slightly higher than observed historically to account for wetter antecedent conditions.

12. LOSS RATES. - Previous studies by this office (refer to office report entitled "Standard Project and Spillway Design Floods, Kern River, California," dated July 1965) evaluated losses using a family of loss curves which related the effects of ground wetness and precipitation rates upon losses. Average loss rates derived from these curves for standard project flood computations were .19 and .22 inches per hour for the North Fork Kern River above Isabella and the South Fork Kern River above Isabella, respectively. Higher loss rates on the South Fork were adopted because soils on the South Fork were believed to be more pervious than those on the North Fork. An examination of available soils maps appears to confirm this conclusion, however, much of the soil cover with low permeabilities on

the North Fork is located at the higher elevations (above 10,000 to 11,000 feet) which were non-contributing during previous major storm periods. Accordingly, the differences in loss rates between the South Fork and North Fork may not be as significant as previously believed when consideration is given to contributing areas. The soils maps also indicate that losses on the local areas below Isabella should be about the same as those on the South Fork.

Losses used in this study were evaluated using the initial wetting loss and constant infiltration loss concept. Satisfactory reconstitutions of historical events could not be obtained using the family of loss curves used in the previous studies. The constant losses determined from an analysis of the 1966 and 1969 floods are tabulated below.

Basin	Subarea	Loss Rates (in/hr) 1966	1969
N. Fork Kern R. above Isabella	8	.33	.25
	7	.33	.25
	6	.34	.20
	5	.34	.20
	41	.22	.18
Weighted N. Fork Average:		.32	.21
S. Fork Kern R. above Isabella	9	non-contrib 1/	non-contrib 1/
	10	.22	.16
	3	.20	.11
	42	.22	.18
Weighted S. Fork Average:		.22	.16
Kern River below Isabella	2	.24	.07
	1	.24	.07

1/ Entire area above snowline

These loss rates are in direct conflict with the analysis of soil types discussed previously. North Fork losses are higher than South Fork losses and the losses for the local areas below Isabella for the 1969 flood are extremely low. These discrepancies are probably due to inadequate precipitation data, primarily on the South Fork where very little precipitation data is available. Accordingly, losses for the North Fork are probably more reliable than those computed for the South Fork. In view of these facts, a constant loss rate of 0.25 inches per hour was adopted for computation of the standard project flood. This figure is less than the average of the computed North Fork losses for the 1966 and 1969 floods. A higher loss rate for the South Fork was not used. A lower loss rate of 0.20 inches per hour was adopted for computation of the probable maximum flood. Initial wetting losses of zero were adopted for computation of the standard project and probable maximum floods since antecedent conditions prior to the onset of these floods would be very wet.

13. UNIT HYDROGRAPHS. - Unit hydrographs for this study were developed using the modified Los Angeles District S-curve procedure presented in Technical Bulletin No. 5-550-3, "Flood Prediction Techniques," dated February 1957. This procedure utilizes a non-dimensional summation graph (S-curve) in conjunction with a basin factor ($\bar{n}$), which relates lag times to basin characteristics, to develop unit hydrographs. The adopted S-curve used in this study is shown on chart 9. Lag time relationships are shown on chart 10. The adopted S-curve was prepared from the unit hydrograph for the Kern River Basin above Isabella that was developed by this office and presented in the July 1965 office report discussed in the previous paragraph. An $\bar{n}$ value of .06 was found to reproduce the lag times of the unit hydrographs developed in the earlier studies. This value was used to develop unit hydrographs which satisfactorily reproduced the historical floods. Accordingly, an $\bar{n}$ value of .06 was adopted to develop unit hydrographs for computation of standard project floods.

Unit hydrographs for probable maximum flood computations were computed using an $\bar{n}$ value of .05 to account for increased hydraulic efficiency of the basins during the occurance of a probable maximum storm. This produces unit hydrographs with peaks about 15 percent higher and lag times about 15 percent shorter than those used for standard project flood computations.

Appropriate adjustments were made in all unit hydrograph computations to account for differences in contributing areas. Unit hydrograph ordinates used for each storm analyzed and for computation of standard project and probable maximum floods are shown on table 1.

14. FLOOD ROUTINGS. - A Kern River routing schematic is shown on chart 8. Flow routings between the various index points were accomplished using Tatum's procedure. Tatum routing steps are shown on chart 8. This routing procedure is verified by the flood reconstitutions, chart 11.

CHAPTER IV
FLOW FREQUENCY ANALYSIS

15. GENERAL. - Unregulated condition rainflood flow-frequency curves (peak and volume) were prepared for the Kern River at Isabella Dam and at Bakersfield. In addition, a regulated condition rainflood peak flow-frequency curve was prepared for Bakersfield. The period October through March was chosen for analysis of rainfloods since historically these floods have occurred during this period. Floodflows for the remainder of the year are influenced by snowmelt. An analysis of snowmelt floods is not required for this study. Details of the rainflood flow-frequency analysis are discussed in the following paragraphs.

16. BAKERSFIELD UNREGULATED CONDITION. - Eighty-three years of recorded flow data are available at the Bakersfield stream gage. The record has been impaired since April 1953 by the operation of Isabella Lake. Accordingly, adjustments to this record are required to obtain a uniform unregulated flow record. These adjustments have been computed by the Kern River Watermaster and are presented in his annual reports. Peak flows are not available for the entire period of record. Peak flows for the 1967 and 1969 water years were estimated by routing Isabella inflow to Bakersfield using the hydrologic model of the basin developed in this study. Peak flows for the remaining missing years were estimated by multiple correlation with the 1-day flows at Bakersfield and with peak flows at the Kern River near Kernville gage (65 years of record), the South Fork Kern River near Onyx gage (52 years of record), the Kern River at Kernville gage (30 years of record), and with Isabella inflows (31 years of record). These correlations were made using the HEC "Regional Frequency Computation" computer program. Correlation coefficients ($\bar{R}$) ranged from .96 to .99. A tabulation of recorded and estimated flows and statistical parameters appears on table 2. Flow-frequency curves are shown on charts 12 and 13 and include the expected probability adjustment. Adopted statistics for the peak, 1-day, and 30-day curves are also presented on table 2. Generalized skew coefficients of 0.7 for the peak and 1-day duration and 0.4 for the 30-day duration were adopted. The 3-, 7-, and 15-day curves are graphical curves drawn to give consistent volume-duration relationships. Volume-duration curves are shown on chart 14. The resulting frequency curves are consistent among themselves and fit the historical data quite well.

An attempt was made to use the statistic smoothing capabilities of the Regional Frequency Computation program. The results were not adopted because the longer duration curves were skewed upward excessively and did not fit the recorded data.

17. ISABELLA UNREGULATED CONDITION. - Kern River flows near Isabella Dam were recorded from 1946 to 1953 at the Kern River below Isabella stream gage. Since 1953 inflows to Isabella Lake have been computed from reservoir operation records.

The record at Isabella has been extended by multiple correlation with records at the Bakersfield gage, the Kern River near Kernville gage, the South Fork Kern River near Onyx gage and the Kern River at Kernville gage. The correlations were made using the HEC "Regional Frequency Computation" computer program. Correlation coefficients ($\bar{\bar{R}}$) for the peak and all durations ranged from .89 to .99. A tabulation of recorded and estimated flows and statistical parameters appears on table 2. Flow-frequency curves are shown on charts 15 and 16 and include the expected probability adjustment. Adopted statistics for the peak, 1-day, and 30-day curves are also presented on table 2. The adopted means are based on the extended record while adopted standard deviations are those developed for the Bakersfield gage. The Bakersfield standard deviations were adopted because they are believed to be more reliable due to the longer record. Skew coefficients are identical to those adopted for the Bakersfield gage. The 3-, 7-, and 15-day curves are graphical curves drawn to give consistent volume-duration relationships. Volume-duration curves are shown on chart 17. The resulting frequency curves are consistent among themselves and with the curves for the Bakersfield gage. They also fit the historical and estimated data quite well.

18. <u>BAKERSFIELD REGULATED CONDITION PEAK CURVE</u>. - An existing condition peak flow-frequency curve at Bakersfield, reflecting the regulation by Isabella Lake, is required for project evaluation studies. This curve is presented on chart 18. A graphical analysis of the recorded daily flows since 1953 was used to define the lower portion of this curve. Daily flows were used, except for water year 1967 (December 1966 flood), because peak flows were not available and the lower regulated daily flows are not significantly different than the lower regulated peak flows. This data was not adequate to define the upper portion of the curve. A review of the past operation of Isabella Lake indicated that during the larger rainfloods the peak flows at Bakersfield (specifically December 1966 and January 1969) resulted almost entirely from local runoff that originated below the dam. Reservoir releases contributed very minor amounts ($\pm$ 400 cfs) to downstream peak flows. Operation studies of Isabella Lake, which consisted of routing hypothetical rare flood events through the reservoir, confirmed this observation. For example, a routing of the SPF produced by a storm centered over the North Fork above Isabella Lake produces a peak flow at Bakersfield that is substantially less than the SPF produced by a storm centered over the local area below Isabella Lake. Accordingly, the upper portion of the frequency curve was defined using an analysis of annual peak rainfloods produced by the local area below Isabella Lake.

Thirty-one years of daily flows from the local area below Isabella was obtained by subtracting Isabella outflows, or recorded flows at the below Isabella gage (flows routed to Bakersfield), from the recorded flows at Bakersfield. Peak local flows for a portion of this entire period could not be determined from the available data.

Peak flows for the missing years were estimated by correlation with 1-day local flows using the HEC "Regional Frequency Computation" program. The correlation coefficient ($\bar{R}$) was .98. An attempt was made to extend this record by correlation with the longer, unregulated condition, total flow record at Bakersfield. These results were not used because of the low degree of correlation. A statistical analysis of the peak local flow data was made assuming that the December 1966 flood was the largest in the last 83 years (based on records at Bakersfield). This analysis was made in accordance with WRC guidelines. This frequency curve is shown on chart 18. A flow of about 1000 cfs was added to this curve to account for reservoir releases. The resulting existing condition peak flow frequency curve at Bakersfield is also shown on chart 18.

CHAPTER V
STANDARD PROJECT FLOODS

19. GENERAL. - Standard project rain floods at Isabella Dam, at Bakersfield, and for the local area below Isabella and above Bakersfield have been developed. Standard project snowmelt floods are not required for this study.

20. STANDARD PROJECT STORM. - Standard project general rain storm amounts were determined using the Sacramento District's April 1971 standard project storm criteria report entitled "Standard Project Criteria for General and Local Storms, Sacramento-San Joaquin Valley, California." Four storm centerings were investigated. These centerings consisted of a centering over the entire area above Isabella, a centering over the North Fork Kern River with a concurrent storm over the South Fork, a centering over the South Fork with a concurrent storm over the North Fork, and a centering over the local area below Isabella with a concurrent storm above Isabella. The centering over the North Fork Kern River with a concurrent storm over the South Fork produced the largest flow at Isabella Lake and at Bakersfield (assuming no regulation by Isabella) while the centering over the local area below Isabella produced the largest runoff from the local area. These centerings were adopted for computation of standard project floods. Storm and snowmelt amounts and other pertinent information for these storm centerings are tabulated below.

	Standard Project Storm Amounts (96 hr)					
	Storm Centered Over North Fork			Storm Centered Over Local Area		
Basin	Precip (in)	Precip as Rain(in)	Snowmelt (in)	Precip (in)	Precip as Rain(in)	Snowmelt (in)
North Fork	17.88	17.24	2.83	15.61	15.05	2.35
South Fork	8.66	8.40	2.67	9.19	8.80	2.80
Local below Isabella	5.56	5.56	0	11.43	11.43	0

Distribution of precipitation to the various subareas was made in proportion to the normal annual precipitation of the subareas. Distribution of snowmelt amounts were made in accordance with the standard project storm criteria report. Subarea amounts for the storm centered over the North Fork are presented in the following table.

Subarea	Standard Project Storm Amounts (96 hr) Precip as Rain (in)	Snowmelt (in)	Total Moisture (in)
8	18.01	3.12	21.13
7	20.45	3.70	24.15
6	18.48	2.99	21.47
5	14.36	2.38	16.74
41	10.47	1.02	11.49
9	10.83	2.66	13.49
10	9.57	3.60	13.17
3	7.32	2.17	9.49
42	6.45	1.81	8.26
2	6.50	0	6.50
1	4.40	0	4.40

Time distribution of total moisture was determined using criteria presented in the Sacramento District's April 1957 standard project storm criteria report entitled "Standard Project Rain-Flood Criteria, Sacramento-San Joaquin Valley, California." This distribution was used in lieu of that presented in the April 1971 criteria report because it gives a more reasonable relationship between peak flow and flood volume.

21. STANDARD PROJECT FLOODS. - Standard project floods were computed using the unit hydrograph, loss rate, flood routing, base flow, and storm criteria discussed in previous paragraphs. In accordance with the standard project storm criteria all precipitation above an elevation of 10,000 feet would fall as snow. Accordingly, the area above this elevation was assumed to be non-contributing. Contributing areas for the various subareas are listed on table 1. Standard project flood amounts are tabulated below; hydrographs are shown on chart 19.

Index Point	Drainage Area (sq mi)	Contributing Drainage Area (sq mi)	Storm Centering	Standard Project Flood Peak Flow (cfs)	6-Day Volume (ac-ft)
Isabella Dam	2074	1825	North Fork	175,000	460,000
Bakersfield 1/	2407	2158	"	161,000	465,000
Local area below Isabella Dam	333	333	Local Area	22,000	38,600

1/ SPF for unregulated condition

22. STANDARD PROJECT FLOOD SERIES. - A 30-day standard project flood series for the Kern River at Isabella Dam was developed for project operation studies. This series, as plotted on chart 17, was developed

to be consistent with the volume-duration curves for the Kern River at Isabella Dam. Pertinent data for the series is tabulated below.

Duration (days)	Volume (cfs - days)	Time Order of Occurence
5	232,000 (main wave)	3rd
"	18,000	2nd
"	11,000	4th
"	7,000	1st
"	4,000	5th

CHAPTER VI
PROBABLE MAXIMUM FLOOD

23. GENERAL. - This chapter presents an estimate of the probable maximum flood for the Kern River at Isabella Lake.

24. PROBABLE MAXIMUM PRECIPITATION. - Probable maximum precipitation (PMP) was determined by the Hydrometeorological Branch of the National Weather Service using Hydrometeorological Report No. 36, "Interim Report, Probable Maximum Precipitation in California," dated October 1961 and revised October 1969. PMP indices maps from this report are shown on charts 20 and 21. the January-February period was found to produce the highest total precipitation and was adopted for computation of the probable maximum flood. The PMP amount for the entire area above Lake Isabella is 23.6 inches. This amount was distributed to the North Fork and South Fork basins assuming a storm centered over the North Fork with a concurrent storm centered over the South Fork. This centering is identical to that used for computation of the standard project flood (refer to Chapter V). Resulting PMP amounts for the North Fork and South Fork basins are 27.3 and 19.4 inches, respectively.

25. SNOW EFFECTS. - An initial snowpack, as shown on chart 22, was assumed to exist at the beginning of the probable maximum storm. This pack is based on a snow cover slightly larger than that used for standard project storm computations. Refer to the Sacramento District's April 1971 standard project storm criteria report entitled "Standard Project Criteria for General and Local Storms, Sacramento-San Joaquin Valley, California." The snow pack was assumed to extend down to an elevation of 3000 feet on the North Fork and 4000 feet on the South Fork. This difference in the lower edge of the snowpack was based on aerial observations of snowpack conditions made after major snow storms. Potential snowmelt rates associated with the probable maximum storm were computed for each 1000 foot elevation band by use of the melt equation for rain-on-snow conditions and partly forested areas given in EM 1110-2-1406. Wind and temperature data for use in this equation were determined from Hydrometeorological Report No. 36. PMP amounts were distributed to the various elevation zones in proportion to the normal annual precipitation of the elevation zones. Precipitation was assumed to fall as rain when temperatures were above $32^{\circ}F$.

The influence of the snowpack on runoff was determined using a computational procedure developed by the Bureau of Reclamation and described in Engineering Monograph No. 35, "Effect of Snow Compaction on Runoff From Rain on Snow" dated June 1966. The procedure is basically a water-budget analysis which accounts for the water in the snowpack until it is released in drainage. It uses the concept of "threshold density" and recognizes the compaction (shrinkage) of the snowpack as water is added. "Threshold density", defined as the density of the snowpack at which compaction ceases and drainage from the pack begins, was assumed to be 40 percent. This procedure is similiar to that presented in EM 1110-2-1460. The primary difference is that the EM procedure assumes that the initial snowpack is "ripe" (at "threshold density") over the entire basin whereas the USBR procedure allows the adoption of an initial snowpack with densities varying with elevation. The assumption of a "ripe" pack throughout the basin would not be realistic for the Kern River and is not consistent with previously approved similiar studies conducted by this office.

Total excess water was computed for each 1000 foot elevation band using a 2 hour time interval. The following tabulation summarizes the rain-on-snow computations. As indicated, the areas above 9000 feet are non-contributing.

NORTH FORK

Elev. band	Band Area (sq mi)	Band Exposure Constant	Antecedent Snow Cover Density (%)	Antecedent Snow Cover Depth (in)	Total Precip (in)	Total Snowmelt (in)	Total Excess Water (in)	Remaining Snow Cover Density (%)	Remaining Snow Cover Depth (in)
2600-3000	26	.60	0	0	10.37	0	10.37	0	0
3000-4000	50	.60	30	6.7	14.11	2.01	16.21	0	0
4000-5000	78	.60	30	19.3	19.84	6.13	25.63	0	0
5000-6000	126	.60	25	36.4	24.27	10.94	33.37	0	0
6000-7000	158	.60	20	59.0	27.50	10.59	34.10	40	13.0
7000-8000	150	.60	15	92.7	27.98	6.67	27.57	40	35.8
8000-9000	144	.75	15	103.3	29.60	3.18	21.27	31	76.0
9000-10000	117	.90	15	112.0	29.10	0	0	29	159.8
Basin Mean1/					25.12	6.95	27.14		

SOUTH FORK

Elev. band	Band Area (sq mi)	Band Exposure Constant	Antecedent Snow Cover Density (%)	Antecedent Snow Cover Depth (in)	Total Precip (in)	Total Snowmelt (in)	Total Excess Water (in)	Remaining Snow Cover Density (%)	Remaining Snow Cover Depth (in)
2600-3000	53	.60	0	0	10.14	0	10.14	0	0
3000-4000	93	.60	0	0	12.59	0	12.59	0	0
4000-5000	94	.60	30	6.7	14.20	2.01	16.21	0	0
5000-6000	130	.60	25	22.8	16.01	6.60	21.71	0	0
6000-7000	192	.60	20	44.5	17.27	9.62	24.39	40	4.5
7000-8000	187	.60	15	77.3	19.70	6.11	20.39	40	27.3
8000-9000	161	.75	15	90.7	27.21	3.76	20.39	31	66.2
9000-10000	66	.90	15	102.0	24.01	0	0	28	140.6
Basin Mean1/					18.14	5.10	19.60		

1/ Basin means for area below 9000'.

Distribution of the excess water to the various subareas was made in proportion to the percentage of each subarea in each elevation zone. The following tabulation indicates total excess water for each subarea.

Subarea	Drainage Area Below 9000' (square miles)	Total Excess Water (in)
North Fork		
8	208	26.49
7	104	28.52
6	178	29.62
5	160	27.24
41	82	21.59
South Fork		
9	85	20.39
10	372	21.49
3	101	19.29
42	352	17.49

26. <u>PROBABLE MAXIMUM FLOOD</u>. - The probable maximum flood inflow to Isabella Lake was computed using the unit hydrograph, loss rate, base flow, flood routing, and storm criteria discussed previously. The flood has a peak flow of 530,000 cfs and a 6-day volume of 1,105,000 acre-feet; a hydrograph is shown on chart 23.

CHAPTER VII

OTHER HYDROLOGIC CONSIDERATIONS

27. <u>FREEBOARD REQUIREMENTS</u>. - Freeboard allowances for wave runup and wind setup were determined in accordance with ETL 1110-2-221, entitled, "Wave Runup and Wind Setup on Reservoir Embankments," dated November, 1976. Computations of wave runup and wind setup required the determination of wind velocities and durations and an evaluation of effective fetch for the reservoir. Effective fetch was determined from the fetch diagram, chart 24. Maximum fetch towards the dam is from the northeast. Wind velocity, duration, and direction information were based on a study of wind records at the Bakersfield weather station since this information is not readily available at Isabella Lake. Suitable records at Bakersfield are available since 1956. A frequency analysis of the annual maximum winds from the northerly, north easterly, and easterly directions was made to determine appropriate wind velocities. The estimated 100-year wind velocities were adopted for use. These overland wind velocities (45 miles per hour for 1 minute duration and 30 miles per hour for 3 hour duration) were used to determine the design wind velocity and duration at Isabella Dam. A summary of the wave runup and wind setup computations are tabulated below.

Effective fetch (mi)	2.85
Over-water to over-land wind velocity ratio	1.25
Design direction	
Wind direction	NE
Wind velocity (mph)	41
Wind duration (min)	39
Design Wave	
Significant wave ht. (Hs- ft)	2.9
Significant wave period (Ts sec.)	3.4
Wave Runup	
Side slope of dam	2.5 to 1
Significant runup (Rs - ft)	3.0
Maximum runup (Rmax - ft)	4.5
Wind setup (S - ft)	0.1
Wave runup plus wind setup (Rmax + S)	4.6

Based on the above, and in accordance with minimum freeboard allowances presented in EC 1110-2-27 entitled, "Policies and Procedures Pertaining to Determination of Spillway Capacities and Freeboard Allowances for Dams," dated August 1966, the dam crest elevation should be established to provide a freeboard above the maximum spillway design flood pool level as follows:

a. A freeboard of 5 feet if 50 percent of the flood reservation is available at the flood onset.

b. A freeboard equal to wave runup plus wind setup (Rmax + S) if the reservoir is at gross pool level at the flood onset.

28. EVAPORATION. - The enlargement of Isabella Lake (increase of minimum pool) would result in additional evaporation losses due to a larger reservoir surface area. These additional losses must be accounted for in project formulation studies since additional evaporation losses will result in a decrease in conservation yield. Evaporation losses from the existing reservoir are computed from evaporation pan records using the procedures presented in the Reservoir Regulation Manual for Isabella Lake, dated May 1953 and revised January 1978. These procedures have been accepted by the local irrigation districts for use in computing reservoir evaporation losses, inflow to Isabella Lake, and water entitlements. Computed annual lake evaporation has ranged from a low of 57.5 inches during water year 1967 (a high runoff year) to a high of 83.3 inches during water year 1977 (a low runoff year). Average annual lake evaporation for the period of record (1955 through 1977) is 67.6 inches. Computed yearly evaporation amounts for the period of record are tabulated on chart 25. A complete record of monthly amounts for the period of record can be obtained from reservoir operation records. Yearly evaporation losses for periods prior to 1955 can be roughly approximated from the correlation curve, chart 25.

29. SEDIMENT YIELD. - Periodic observations of sediment accumulations in Isabella Lake have been made since operation began in 1953. Only small amounts of deposition were observed prior to the large rainflood of December 1966. Substantial amounts of sediment were deposited by this flood and also by the January 1969 flood. Three surveys to determine the amount of deposited sediment have been made. These surveys are discussed in an Office Report dated 24 February 1971, subject: "Sedimentation Survey of Isabella Lake." The results of these surveys are tabulated on the following page.

Date of Survey	Type of Survey	Total sediment deposits (acre-feet)
October 1956	Reconnaissance	500
December 1968	Reconnaissance	5,200
March 1969	Instrument	6,540

Based on this data the average amount of sediment deposited from 1953 to 1969 was about 410 acre-feet per year or about 0.2 acre-feet per year per square mile. This figure is probably on the high side of the long term average because the period analyzed contains the two largest rain floods of record in the last 83 years (records have been maintained at the Bakersfield gage since water year 1894). Accordingly, an adjustment was made to this figure to reflect long term averages. Since most of the sediment is deposited during rainflood periods this adjustment was based on a comparison of rainflood volumes at the Bakersfield gage using a ratio of the average of the maximum annual 7-day rainflood volumes for the 1894 through 1976 period to the corresponding average volumes for the 1953 through 1969 period. This adjustment reduces the average annual sediment deposition rate in Isabella Lake to 0.13 acre-feet per year per square mile. Using this figure the estimated 100-year sediment accumulation in Isabella Lake is 27,000 acre-feet. No adjustment to this figure is required for reservoir trap efficiency since the measured sediments include only the deposited sediments.

Distribution of the sediment in the reservoir is based on the March 1969 survey and is tabulated below:

Elev.	Percent Below Given Elev.
2605.5 (Spillway Crest)	100
2600	99
2580	97
2560	87
2540	34
2520	5
2500	0

TABLE-I

UNIT HYDROGRAPH CHARACTERISTICS AND ORDINATES
DRAINAGE AREA BELOW 7,000 FEET FOR JANUARY 1969 FLOOD REPRODUCTIONS

SUBAREAS	1	2	3	41	42	5	6	7	8	9	10
CHARACTERISTICS											
TOTAL AREA (Sq. Mi.)	149.0	184.0	101.0	82.0	352.0	163.0	184.0	132.0	530.0	146.0	384.0
CONTRIBUTING AREA PARAMETERS											
AREA (Sq. Mi.)	149.0	174.0	91.0	82.0	314.0	126.0	124.0	43.0	63.0	0	157.0
L (Mi.)	28.9	28.5	19.0	13.8	37.1	19.8	20.6	15.8	20.2		32.4
Lca (Mi.)	15.0	11.1	9.0	4.3	17.4	7.5	5.9	6.7	4.7		15.0
SLOPE (Ft./Mi.)	185.5	181.5	175.0	301.8	123.1	220.9	164.1	146.6	114.4		126.5
$LLca/s^{.5}$	31.8	23.4	12.9	3.4	58.2	10.0	9.5	8.8	8.9		43.3
$\bar{n}$	.06	.06	.06	.06	.06	.06	.06	.06	.06		.06
Lag (Hours)	5.4	4.8	3.8	2.3	6.8	3.5	3.4	3.3	3.3		6.0
S-CURVE	Kern River Basin										
DELTA ELEV. (Ft.)	5350	5162	3320	4165	4565	4365	3380	2318	2307		4100
TWO HOUR UNIT HYDROGRAPH ORDINATES *(End of period flow in c.f.s.)*											
TIME PERIOD *(Hours)*											
2	5661	8353	6578	11437	7544	10319	10392	3759	5457		4723
4	11490	14895	8732	7275	19012	12492	12328	4286	6276		10726
6	9172	10008	4487	3073	18430	5929	5787	1977	2906		9782
8	5130	5793	2681	1802	12813	3468	3374	1148	1688		5768
10	3603	3894	1750	1151	8259	2308	2256	773	1136		4058
12	2594	2758	1296	809	6348	1720	1674	564	832		2906
14	1949	2148	989	455	4809	1238	1203	411	604		2212
16	1568	1756	754	298	3701	1010	982	332	489		1765
18	1321	1373	631	145	3106	768	728	234	349		1450
20	1060	1135	482	12	2591	508	473	151	225		1249
22	880	987	329		2278	369	356	117	173		1033
24	784	818	245		1938	283	266	84	125		849
26	676	617	195		1591	186	152	37	59		775
28	543	446	143		1444	60	42	2	10		684
30	417	371	63		1309						588
32	312	308	9		1167						471
34	276	244			1001						370
36	231	163			814						288
38	188	80			656						260
40	142				518						223
42	62				476						186
44	21				417						152
46					358						87
48					301						56
50					241						
52					116						
54					85						
56											
58											
60											
TOTAL	48080	56147	29364	26457	101323	40658	40013	13875	20329		50661

TABLE - I

UNIT HYDROGRAPH CHARACTERISTICS AND ORDINATES
DRAINAGE AREA BELOW 8,500 FEET FOR DECEMBER 1966 FLOOD REPRODUCTIONS

SUBAREAS	1	2	3	41	42	5	6	7	8	9	10
CHARACTERISTICS											
TOTAL AREA (Sq. Mi.)	149.0	184.0	101.0	82.0	352.0	163.0	184.0	132.0	530.0	146.0	384.0
CONTRIBUTING AREA PARAMETERS											
AREA (Sq. Mi.)	149.0	184.0	101.0	82.0	352.0	158.0	174.0	91.0	154.0	57.0	342.0
L (Mi.)	28.9	30.0	19.0	13.8	41.1	20.6	21.0	19.4	36.7	10.7	37.8
Lca (Mi.)	15.0	11.9	9.1	4.3	17.4	7.5	7.1	10.3	8.1	3.4	18.0
SLOPE (Ft./Mi.)	185.5	185.2	175.0	301.8	120.8	231.9	170.9	197.3	103.6	61.9	148.4
$LLca/s^{.5}$	31.8	26.2	13.0	3.4	65.0	10.1	11.4	14.2	29.2	4.6	55.8
$\bar{n}$	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
Lag (Hours)	5.4	5.0	3.8	2.3	7.0	3.5	3.6	4.0	5.2	2.6	6.6
S-CURVE	Kern River Basin										
DELTA ELEV. (Ft.)	5350	5562	3320	4165	4965	4765	3580	3818	3807	660	5600

TWO HOUR UNIT HYDROGRAPH ORDINATES
(End of period flow in c.f.s.)

TIME PERIOO *(Hours)*	1	2	3	41	42	5	6	7	8	9	10
2	5661	8108	7267	11437	7770	12843	13351	6306	6240	6948	8486
4	11490	15203	9673	7275	20382	15648	17028	8563	12251	5381	21064
6	9172	10909	4989	3073	19853	7456	8389	4559	9351	2288	20334
8	5130	6212	2984	1802	14918	4368	4958	2747	5261	1324	13743
10	3603	4216	1948	1151	9368	2900	3260	1791	3622	872	8984
12	2594	3006	1442	809	7344	2163	2432	1318	2615	627	6803
14	1949	2334	1102	455	5463	1559	1792	1025	1990	427	5198
16	1568	1892	838	298	4344	1271	1428	764	1603	251	3978
18	1321	1532	702	145	3524	975	1152	646	1333	176	3358
20	1060	1210	539	12	2972	649	819	517	1049	88	2814
22	880	1071	369		2598	465	548	368	908	11	2456
24	784	916	273		2253	360	438	256	794		2072
26	676	730	218		1894	246	327	210	668		1708
28	543	548	161		1614	81	177	161	516		1572
30	417	408	73		1502		48	98	384		1410
32	312	355	13		1350			35	312		1250
34	276	292			1203				269		1051
36	231	231			1019				220		850
38	188	135			833				174		672
40	142	66			671				90		556
42	62				546				43		506
44	21				505						439
46					444						373
48					383						312
50					325						212
52					264						110
54					134						47
56					109						
58											
60											
TOTAL	48080	59374	32591	26457	113585	50984	56147	29364	49693	18393	110358

TABLE-I

UNIT HYDROGRAPH CHARACTERISTICS AND ORDINATES
DRAINAGE AREA BELOW 9,000 FEET FOR PROBABLE MAXIMUM FLOOD COMPUTATIONS

SUBAREAS	3	41	42	5	6	7	8	9	10
				CHARACTERISTICS					
TOTAL AREA (Sq. Mi.)	101.0	82.0	352.0	163.0	184.0	132.0	530.0	146.0	384.0
				CONTRIBUTING AREA PARAMETERS					
AREA (Sq. Mi.)	101.0	82.0	352.0	160.0	178.0	104.0	208.0	85.0	372.0
L (Mi.)	19.0	13.8	41.1	20.6	21.0	20.2	37.9	24.5	39.2
Lca (Mi.)	9.1	4.3	17.4	7.5	7.1	10.4	9.5	8.3	19.0
SLOPE (Ft./Mi.)	175.0	301.8	120.8	231.9	170.9	214.3	113.5	47.4	155.6
$LLca/s^{.5}$	13.0	3.4	65.0	10.1	11.4	14.3	33.7	29.5	59.7
$\bar{n}$	.05	.05	.05	.05	.05	.05	.05	.05	.05
Lag (Hours)	3.2	1.9	5.9	2.9	3.0	3.3	4.6	4.4	5.7
S-CURVE					Kern River Basin				
DELTA ELEV. (Ft.)	3320	4165	4965	4765	3580	4318	4307	1160	6100

TWO HOUR UNIT HYDROGRAPH ORDINATES
(End of period flow in c.f.s.)

TIME PERIOD (Hours)	3	41	42	5	6	7	8	9	10
2	9216	13711	11186	16612	17404	9046	10886	4918	12618
4	10067	6486	24760	15712	17644	10365	18365	7724	27080
6	4578	2758	21991	6986	7908	4790	11555	4528	23211
8	2651	1579	12676	3936	4526	2781	6811	2720	13121
10	1786	1013	9009	2700	3068	1873	4535	1793	9372
12	1281	526	6446	1859	2142	1370	3228	1290	6708
14	957	311	4819	1444	1658	996	2516	1010	4973
16	751	75	3914	983	1213	805	2038	791	4058
18	502		3228	610	755	571	1559	621	3392
20	334		2748	452	552	369	1347	536	2829
22	255		2231	270	389	284	1139	436	2256
24	164		1898	63	169	205	891	319	2005
26	47		1711		7	92	648	225	1770
28			1498			10	488	189	1524
30			1247				414	150	1214
32			982				329	113	942
34			749				244	51	723
36			631				103	13	646
38			555				19		547
40			467						449
42			384						354
44			276						165
46			128						85
48			45						
50									
52									
54									
56									
58									
60									
TOTAL	32589	26459	113579	51627	57435	33557	67115	27427	120032

TABLE-I

UNIT HYDROGRAPH CHARACTERISTICS AND ORDINATES
DRAINAGE AREA BELOW 10,000 FEET FOR STANDARD PROJECT FLOOD COMPUTATIONS

SUBAREAS	1	2	3	41	42	5	6	7	8	9	10
CHARACTERISTICS											
TOTAL AREA (Sq. Mi.)	149.0	184.0	101.0	82.0	352.0	163.0	184.0	132.0	530.0	146.0	384.0
CONTRIBUTING AREA PARAMETERS											
AREA (Sq. Mi.)	149.0	184.0	101.0	82.0	352.0	163.0	184.0	123.0	297.0	139.0	384.0
L (Mi.)	28.9	30.0	19.0	13.8	41.1	20.6	21.0	21.5	38.7	26.9	39.9
Lca (Mi.)	15.0	11.9	9.1	4.3	17.4	7.5	7.1	10.5	13.6	10.8	19.4
SLOPE (Ft./Mi.)	185.5	185.2	175.0	301.8	120.8	231.9	170.9	247.4	137.1	80.3	157.8
$LLca/s^{.5}$	31.8	26.2	13.0	3.4	65.0	10.1	11.4	14.4	44.9	32.4	61.5
$\bar{n}$	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
Lag (Hours)	5.4	5.0	3.8	2.3	7.0	3.5	3.6	4.0	6.1	5.4	6.9
S-CURVE	Kern River Basin										
DELTA ELEV. (Ft.)	5350	5562	3320	4165	4965	4765	3580	5318	5307	2160	6300

TWO HOUR UNIT HYDROGRAPH ORDINATES

(End of period flow in c.f.s.)

TIME PERIOD *(Hours)*	1	2	3	41	42	5	6	7	8	9	10
2	5661	8108	7267	11437	7770	13250	14118	8471	8682	5208	8846
4	11490	15203	9673	7275	20382	16143	18008	11530	19981	10644	22736
6	9172	10909	4989	3073	19853	7692	8872	6178	18448	8578	22118
8	5130	6212	2984	1802	14918	4503	5242	3728	11038	4796	15976
10	3603	4216	1948	1151	9368	2993	3448	2430	7708	3382	10141
12	2594	3006	1442	809	7344	2233	2571	1786	5533	2432	7902
14	1949	2334	1102	455	5463	1608	1894	1392	4250	1823	5924
16	1568	1892	838	298	4344	1312	1509	1036	3356	1468	4622
18	1321	1532	702	145	3524	1005	1219	876	2758	1238	3826
20	1060	1210	539	12	2972	669	866	706	2384	998	3198
22	880	1071	369		2598	480	580	505	1990	822	2814
24	784	916	273		2253	372	464	349	1616	735	2418
26	676	730	218		1894	254	346	288	1472	635	2003
28	543	548	161		1614	84	187	221	1306	515	1762
30	417	408	73		1502		50	142	1138	397	1620
32	312	355	13		1350			52	925	295	1451
34	276	292			1203				735	259	1274
36	231	231			1019				561	219	1053
38	188	135			833				500	179	860
40	142	66			671				435	139	672
42	62				546				367	63	589
44	21				505				303	28	532
46					444				211		462
48					383				104		393
50					325				36		331
52					264						218
54					134						119
56					109						51
58											
60											
TOTAL	48080	59374	32591	26457	113585	52598	59374	39690	95837	44853	123911

TABLE-2

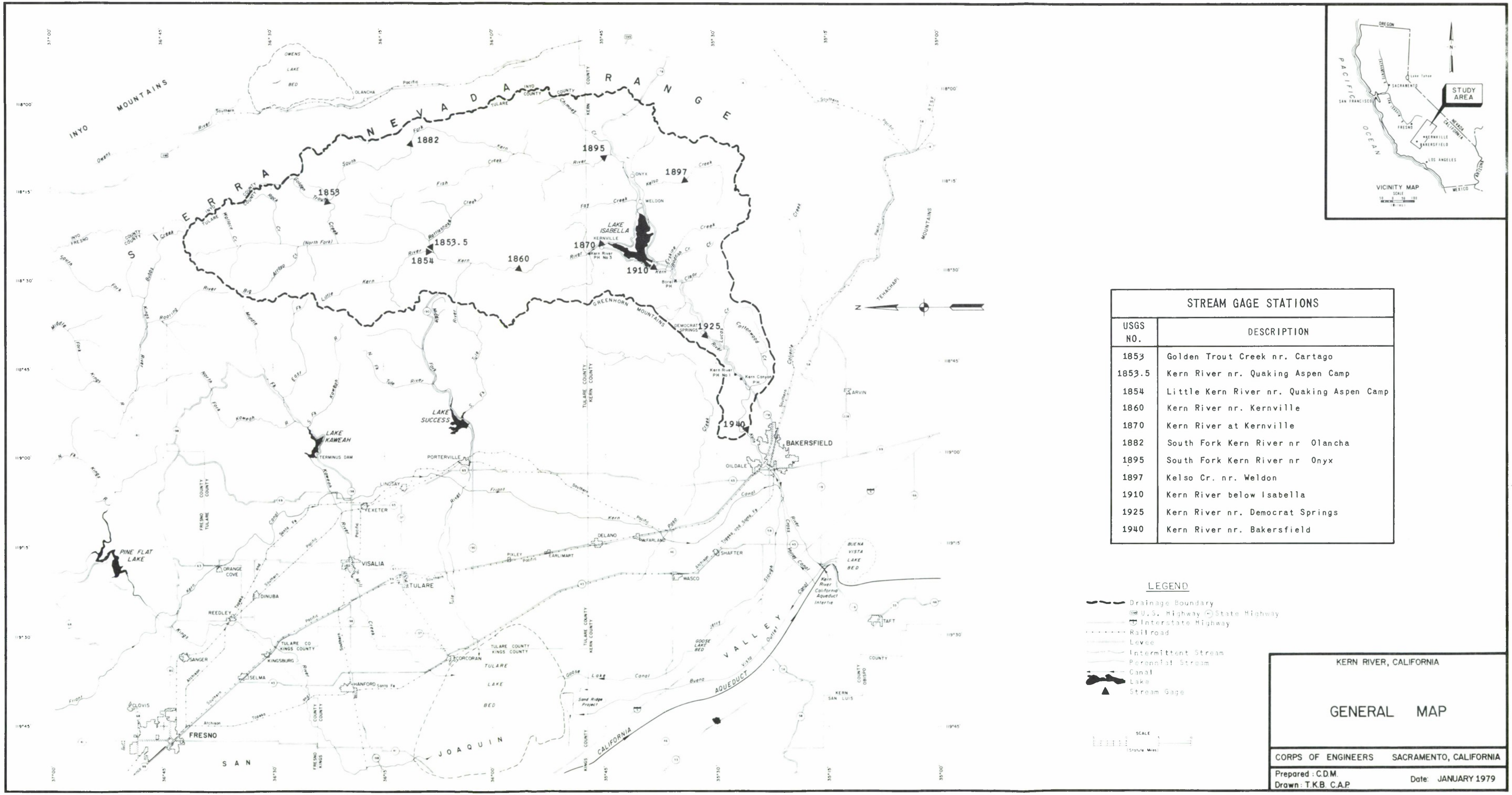
UNREGULATED CONDITION FLOWS - KERN RIVER												
WATER YEAR	NEAR BAKERSFIELD						ISABELLA LAKE INFLOW					
	PEAK	1 DAY	3 DAY	7 DAY	15 DAY	30 DAY	PEAK	1 DAY	3 DAY	7 DAY	15 DAY	30 DAY
1894	1908 E	1440	1390	1220	1120	1010	3763 E	3763 E	2231 E	1660 E	1227 E	720 E
1895	7249 E	4760	2990	2110	1650	1450	5123 E	4339 E	3179 E	2391 E	1743 E	1291 E
1896	3584 E	3100	2270	1510	1180	960	2617 E	2262 E	1516 E	1081 E	837 E	652 E
1897	3269 E	2070	1610	1320	1070	930	2328 E	2328 E	1888 E	1603 E	1195 E	937 E
1898	850 E	730	660	560	480	450	532 E	532 E	532 E	532 E	494 E	437 E
1899	4930	3120	2550	1590	910	600	12829 E	4280 E	2425 E	1874 E	1388 E	1029 E
1900	1019 E	750	680	530	450	420	1216 E	781 E	741 E	604 E	498 E	462 E
1901	2613 E	1780	1760	1620	1580	1420	1110 E	1110 E	1110 E	970 E	940 E	732 E
1902	1669 E	1490	1190	1140	940	840	1288 E	1288 E	1214 E	1111 E	927 E	807 E
1903	1467 E	1430	1170	850	670	580	1303 E	1084 E	890 E	712 E	603 E	603 E
1904	1760 E	1760	1580	1130	930	670	1470 E	1470 E	1470 E	1049 E	812 E	812 E
1905	1929 E	1310	1150	1100	1020	840	4020 E	1721 E	1266 E	968 E	847 E	765 E
1906	6937 E	5530	4610	3260	3040	2100	9013 E	8256 E	6859 E	4324 E	3467 E	2168 E
1907	2327 E	2070	1930	1810	1630	1370	2924 E	1753 E	1747 E	1115 E	952 E	887 E
1908	1735 E	1580	1510	1460	1360	1070	3326 E	2182 E	1687 E	1174 E	944 E	789 E
1909	11870	8780	5750	3630	3320	2600	11204 E	7592 E	4281 E	2578 E	2172 E	1894 E
1910	7560	4660	3670	2380	1610	1480	4699 E	4016 E	3052 E	2316 E	2242 E	1626 E
1911	5380	3670	3300	2300	1580	1330	6635 E	4892 E	3094 E	2337 E	1685 E	1033 E
1912	743 E	600	570	540	520	460	379 E	379 E	379 E	379 E	377 E	354 E
1913	578	510	500	490	450	420	608 E	427 E	427 E	425 E	410 E	376 E
1914	18300	15500	11000	6330	3650	2320	11620 E	10321 E	6505 E	3469 E	2978 E	1652 E
1915	1280	1220	1200	1120	1040	800	2373 E	1439 E	1141 E	1140 E	866 E	687 E
1916	18000	10800	6110	5020	4510	3740	23503 E	15106 E	10138 E	6602 E	5837 E	3636 E
1917	1980	1860	1790	1460	1190	1060	1335 E	896 E	896 E	896 E	799 E	799 E
1918	1160	1120	1050	990	940	790	1923 E	1614 E	1184 E	862 E	604 E	544 E
1919	1190	1140	1070	910	690	620	1500 E	1024 E	821 E	732 E	561 E	493 E
1920	1410	1050	910	840	710	660	976 E	976 E	963 E	707 E	628 E	527 E
1921	1200	1160	1070	1000	950	910	1014 E	932 E	932 E	760 E	715 E	715 E
1922	1480	1390	1320	1300	1100	860	1159 E	1159 E	1159 E	958 E	958 E	969 E
1923	890	810	760	650	560	510	1436 E	977 E	893 E	719 E	613 E	525 E
1924	370	330	330	310	270	260	170 E	170 E	170 E	170 E	170 E	170 E
1925	1010	840	740	630	550	510	891 E	689 E	689 E	689 E	619 E	538 E
1926	520	480	460	450	430	410	487 E	376 E	376 E	376 E	376 E	376 E
1927	6570	5170	4250	3160	2420	1780	11180 E	5600 E	3917 E	2897 E	2070 E	1992 E
1928	1810	1680	1490	1190	770	540	2225 E	1362 E	1118 E	940 E	809 E	607 E
1929	730	690	600	550	480	420	429 E	429 E	429 E	429 E	429 E	429 E
1930	1820	1110	960	840	680	570	2055 E	1673 E	1223 E	978 E	758 E	584 E
1931	380	340	330	300	280	260	350 E	350 E	350 E	350 E	350 E	307 E
1932	2260	1570	1500	1390	1260	1120	1675 E	1472 E	1178 E	1178 E	1178 E	1178 E
1933	790	770	710	700	650	600	1349 E	629 E	629 E	620 E	571 E	571 E
1934	650	590	520	490	490	450	689 E	575 E	548 E	541 E	541 E	497 E
1935	630	590	540	470	450	410	464 E	409 E	409 E	409 E	377 E	377 E
1936	2150	1810	1580	1370	1100	950	1605 E	1553 E	1351 E	1313 E	971 E	971 E
1937	20000	14700	8010	4510	3630	2630	13119 E	9041 E	5985 E	3143 E	2468 E	1957 E
1938	14600	11500	6980	4530	3380	2670	19988 E	14996 E	7210 E	3912 E	2291 E	1788 E
1939	1810	1730	1560	1390	1190	890	1727 E	1137 E	1137 E	1112 E	917 E	746 E
1940	5450	2890	2440	1990	1610	1330	4316 E	2013 E	1515 E	1229 E	1110 E	1103 E
1941	2970 E	2970	2340	1980	1810	1760	2960 E	2314 E	2093 E	2047 E	1945 E	1279 E
1942	1780	1590	1400	1180	1110	960	1427 E	1321 E	1285 E	1079 E	938 E	915 E
1943	21700	11900	10600	7040	6200	4360	25055 E	8437 E	6197 E	3922 E	2704 E	2140 E
1944	1880	1520	1400	1250	1190	1150	2136 E	1368 E	1175 E	976 E	807 E	788 E
1945	9370	5670	4460	2640	1760	1230	8137 E	4227 E	2582 E	2169 E	1783 E	1181 E
1946	1910	1730	1580	1370	1110	1000	2498 E	1890	1450	1220	1000	900
1947	3810	2440	1650	1200	890	740	3690	1790	1490	1040	790	670
1948	370	364	364	359	315	266	370 E	370	360	360	320	260
1949	670	402	390	386	375	346	430 E	400	380	360	350	310
1950	4590	2880	1910	1280	910	780	4570	2840	1900	1220	730	660
1951	36000	14700	9800	5470	3260	2500	39500	21500	10500	5500	3090	2420
1952	8340	6732	3620	2363	1803	1396	7070 E	4200	2890	1920	1460	1140
1953	2420	2057	1895	1484	1291	1045	2378 E	2030	1490	1180	1100	910
1954	2120	1170	1072	889	805	765	1990	1407	950	770	690	670
1955	1509 E	1075	920	690	550	487	1242 E	1130	720	580	480	460
1956	24240 E	12700	8010	4890	2890	1850	23000	12800	8010	4850	2830	1800
1957	2152 E	1500	820	720	650	570	830 E	830	740	710	630	550
1958	3008 E	2340	2030	1790	1530	1112	2501 E	2060	1790	1610	1380	1040
1959	891 E	685	637	577	569	545	740 E	730	650	560	560	520
1960	1810 E	1690	1073	769	693	633	2250 E	1570	970	690	630	500
1961	377 E	302	281	256	253	248	320 E	320	270	260	240	220
1962	2835 E	2835	2514	2002	1427	982	980 E	980	940	810	630	530
1963	33788 E	15584	9980	5471	3206	1996	20857 E	15800	9900	5430	3170	1960
1964	950 E	752	693	597	509	446	630 E	630	610	520	440	410
1965	5912 E	4693	2815	2264	1533	1116	6179 E	4360	2690	2150	1450	1030
1966	2117 E	1271	1106	861	713	614	3691 E	2500	2070	1500	1230	1080
1967	90000[2]	80029	37155	18353	9472	5273	120000	72800	35200	17400	9030	5030
1968	1285 E	1046	969	904	875	851	1489 E	1150	970	890	860	830
1969	30000[2]	24216	15000	8713	5705	3693	35000	22400	13400	7970	5110	3290
1970	6622 E	6300	3727	2311	1615	1196	9263 E	5770	3520	2120	1500	1110
1971	1948 E	1275	1232	1130	879	688	1338 E	1300	1240	1110	860	670
1972	857 E	630	627	626	614	547	640 E	640	610	610	600	530
1973	1573 E	1525	1308	1004	912	859	1702 E	1400	1240	900	760	740
1974	2451 E	1609	1484	1324	1277	1211	2360 E	1990	1510	1240	1190	1140
1975	1674 E	1170	1094	933	781	681	1272 E	1230	1090	880	730	650
1976	503 E	503	475	413	378	376	573 E	540	440	380	370	360
COMPUTED STATISTICS												
Log Mean	3.439	3.287	3.205	3.109	3.026	2.948	4.158	3.315	3.195	3.080	2.981	2.899
Std. Dev.	.589	.479	.421	.362	.324	.288	.654	.568	.497	.422	.356	.307
Skew	.596	.838	.746	.624	.546	.453	-.028	1.005	.982	.973	.886	.653
Years	47.0	83.0	83.0	83.0	83.0	83.0	7.0	31.0	31.0	31.0	31.0	31.0
EXTENDED STATISTICS BASED ON MULTIPLE CORRELATION												
Log Mean	3.395	3.287	3.205	3.109	3.026	2.948	3.373	3.254	3.157	3.059	2.977	2.899
Std. Dev.	.517	.479	.421	.362	.324	.288	.558	.498	.429	.362	.318	.274
Skew	.790	.838	.746	.624	.546	.453	.623	.726	.699	.642	.589	.423
Equiv. Years	82.2	83.0	83.0	83.0	83.0	83.0	79.4	80.9	82.4	82.5	82.2	82.0
Correlation Coeff. (with Bakersfield gage)	.99[1]	1.0	1.0	1.0	1.0	1.0	.95	.96	.97	.96	.95	.95
ADOPTED STATISTICS												
Log Mean	3.395	3.287				2.948	3.373	3.254				2.899
Std. Dev.	.517	.479	Graphical			.288	.517	.479	Graphical			.288
Skew	.70	.70				.40	.70	.70				.40

[1] Correlation coefficient of peak with 1-day flows at Bakersfield.

[2] Estimated values using hydrologic model of basin.

NOTE:

(1980E) - E represents an estimated value based on multiple correlation. Refer to paragraphs 16 and 17.



STREAM GAGE STATIONS

USGS NO.	DESCRIPTION
1853	Golden Trout Creek nr. Cartago
1853.5	Kern River nr. Quaking Aspen Camp
1854	Little Kern River nr. Quaking Aspen Camp
1860	Kern River nr. Kernville
1870	Kern River at Kernville
1882	South Fork Kern River nr Olancha
1895	South Fork Kern River nr Onyx
1897	Kelso Cr. nr. Weldon
1910	Kern River below Isabella
1925	Kern River nr. Democrat Springs
1940	Kern River nr. Bakersfield

LEGEND

- Drainage Boundary
- U.S. Highway / State Highway
- Interstate Highway
- Railroad
- Levee
- Intermittent Stream
- Perennial Stream
- Canal
- Lake
- Stream Gage

SCALE (Statute Miles)

KERN RIVER, CALIFORNIA

GENERAL MAP

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: C.D.M.
Drawn: T.K.B. C.A.P.

Date: JANUARY 1979

CHART I

LEGEND

~1000~ Contour in feet

KERN RIVER, CALIFORNIA

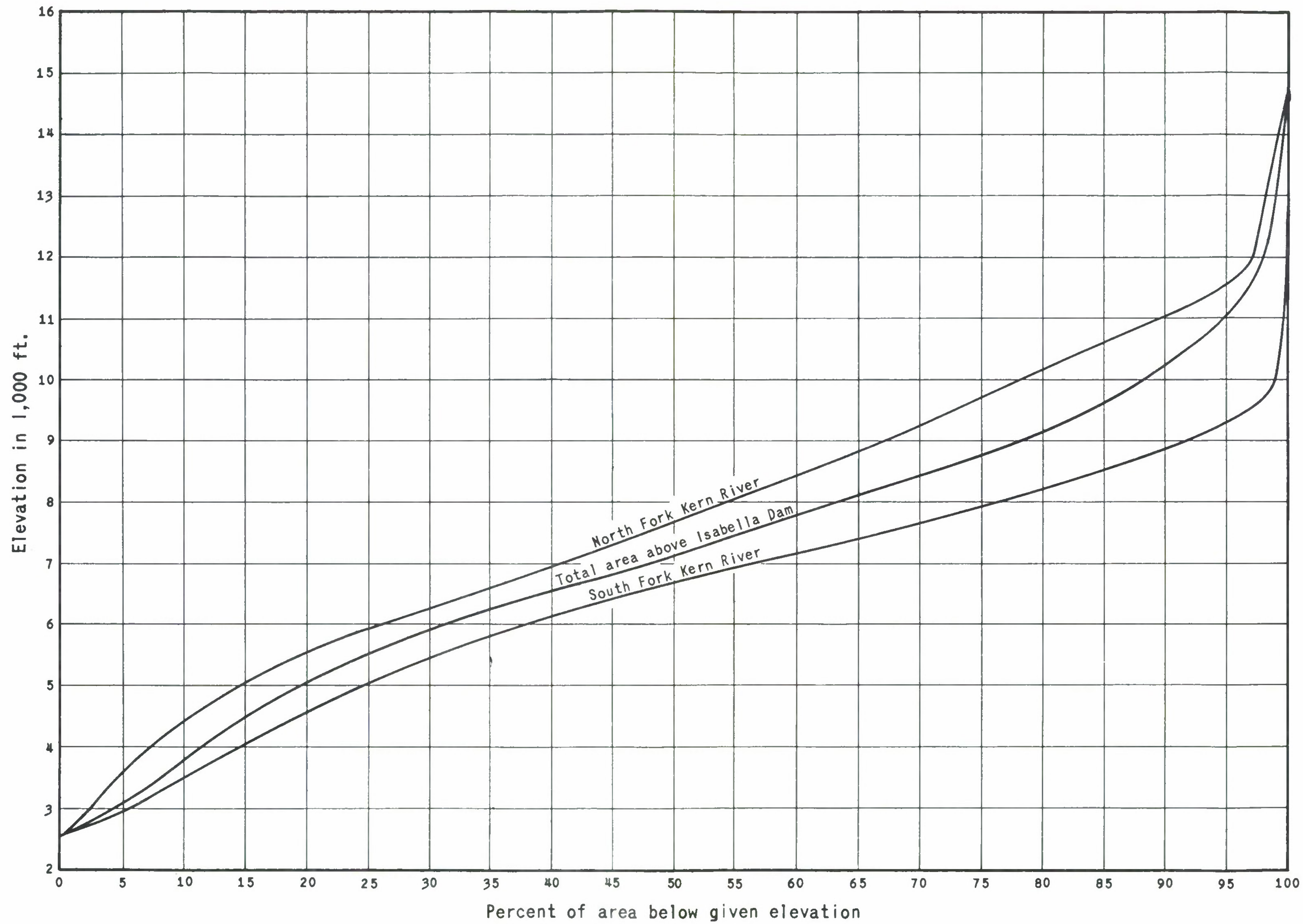
TOPOGRAPHY MAP

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.

Date: JANUARY 1979

CHART 2



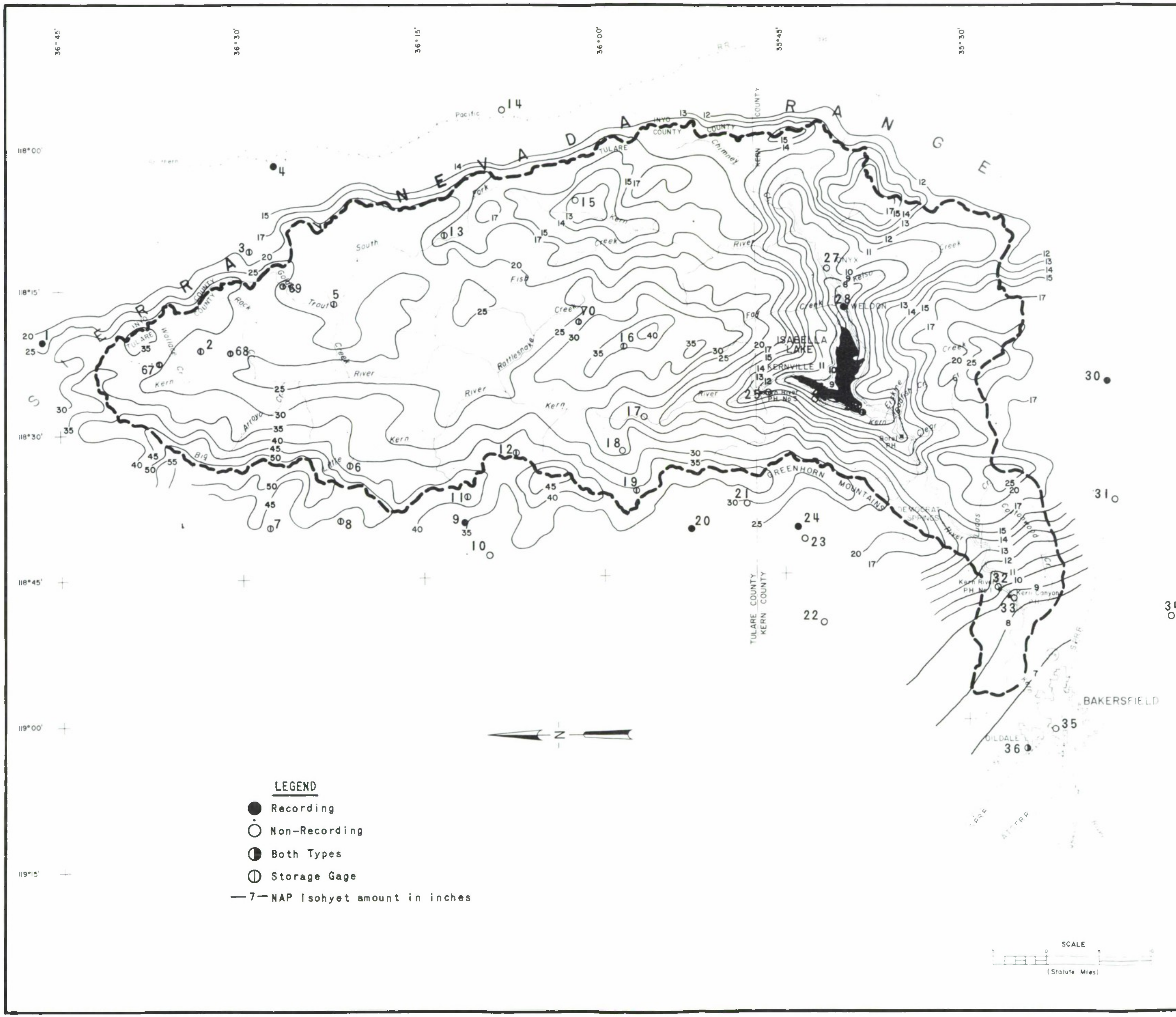
KERN RIVER, CALIFORNIA

AREA - ELEVATION CURVES
(Above Isabella Dam)

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

CHART 3



PRECIPITATION STATIONS

NO.	DESCRIPTION	N.A.P. (Inches)
1	Independence Onion Vly	21.6
2	Crabtree Meadow	22.6
3	Cottonwood Cr.	17.8
4	Lone Pine Cottonwood PH	5.3
5	Tunnel RS	19.6
6	Wet Meadow	36.3
7	Atwell	39.6
8	Hockett Meadow	40.9
9	Springville Tule Hdwks	35.1
10	Springville 7 ENE	27.0
11	Hossack	41.4
12	Quaking Aspen	38.1
13	Monache Meadow	14.9
14	Haiwee	6.0
15	Windy Springs	11.2
16	Round Meadow	35.0
17	Kern Int 3	16.9
18	Johnsondale	24.1
19	Doublebunk	36.0
20	Calif. Hot Spr. RS	23.8
21	Posey 3E	28.8
22	Woody	11.7
23	Glennville	17.2
24	Glennville Fulton RS	18.7
25	Kern PH No. 3	11.7
26	Wofford Hgts	10.0
27	Onyx	9.2
28	Weldon 1 WSW	7.5
29	Isabella Dam	10.4
30	Loraine	13.1
31	Caliente	11.9
32	Kern PH No. 1	10.4
33	Kern Canyon	8.1
34	Arvin	7.2
35	Bakersfield 1W	6.0
36	Bakersfield WB AP	5.7
67[1/]	Bighorn Plateau	
68[1/]	Guyot Flat	
69[1/]	Big Whitney Meadow	
70[1/]	Bonita Meadows	

[1/] Snow Courses – not used for determination of NAP.

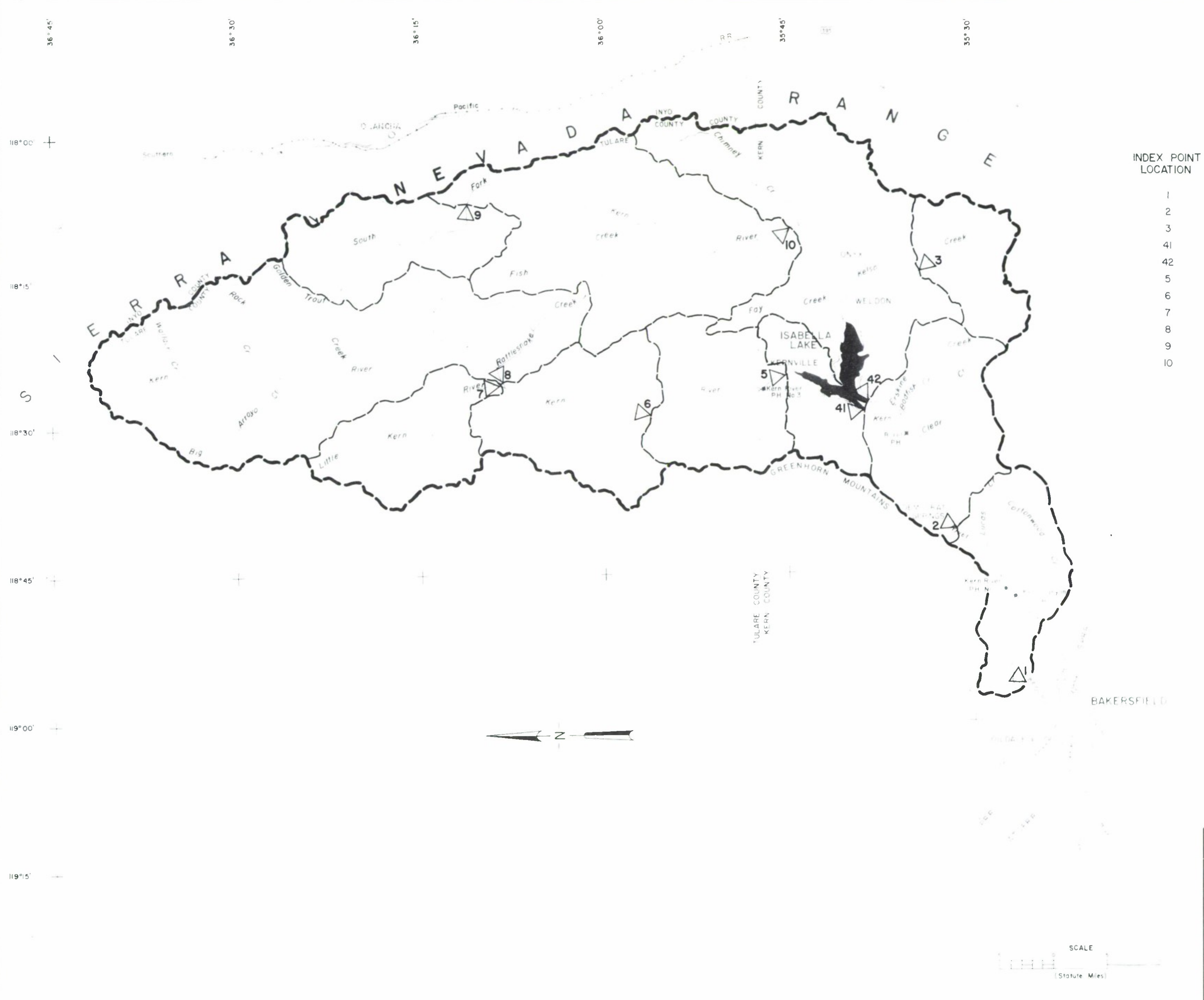
KERN RIVER, CALIFORNIA

NORMAL ANNUAL PRECIPITATION MAP

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

CHART 4



INDEX POINT LOCATION	SUBAREA DESCRIPTION
1	Kern River Near Bakersfield
2	Kern River Near Democrat Springs
3	Kelso Creek Near Weldon
41	Kern River Local Above Isabella Lake
42	South Fork Kern River Local Above Isabella Lake
5	Kern River At Kernville
6	Kern River Near Kernville
7	Little Kern River Near Quaking Aspen Camp
8	Kern River Near Quaking Aspen Camp
9	South Fork Kern River Near Olancha
10	South Fork Kern River Near Onyx

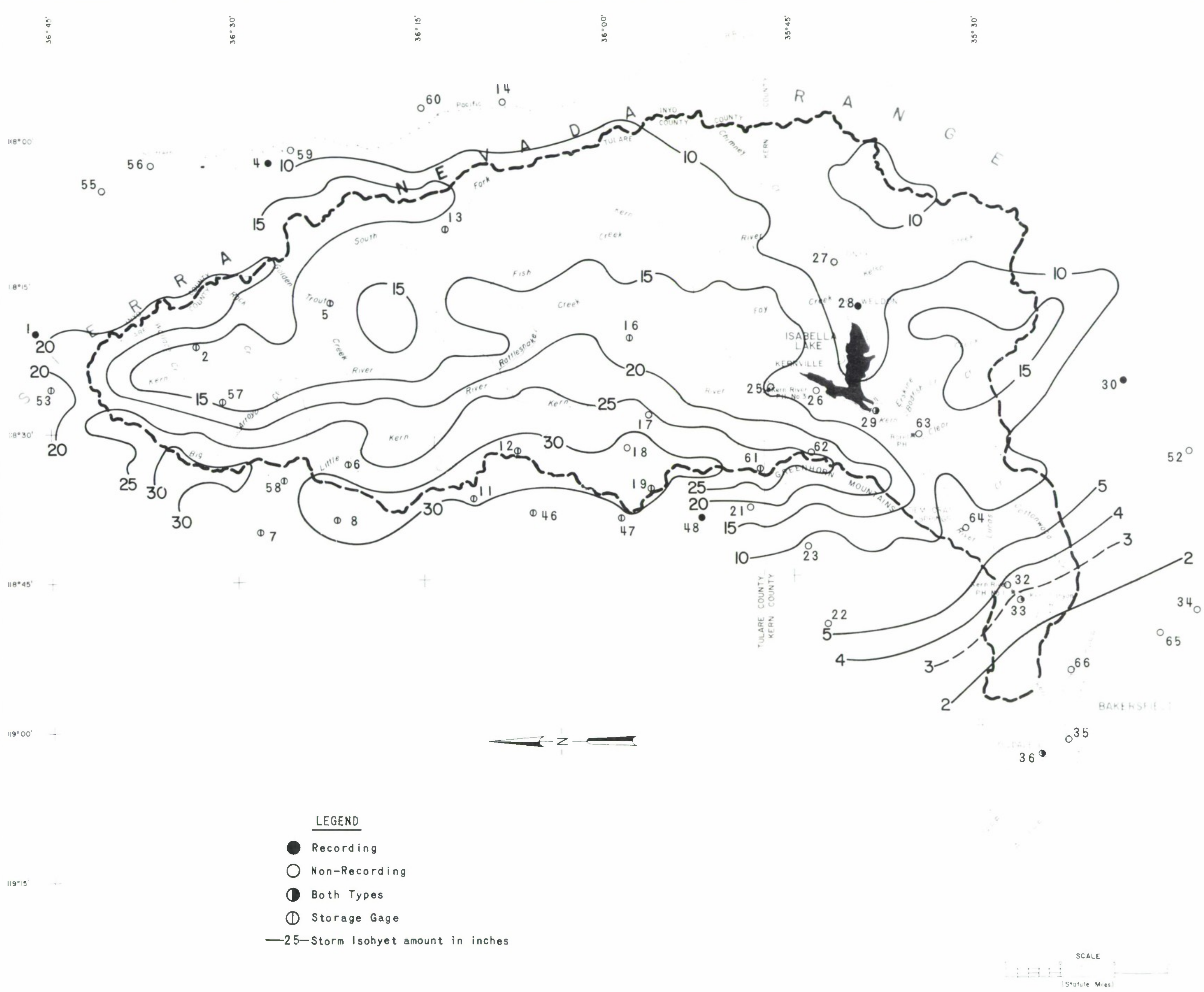
KERN RIVER, CALIFORNIA

SUBAREA MAP

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

CHART 5



NO.	DESCRIPTION	STORM AMOUNT (Inches)
1	Independence Onion Vly	10.7
2	Crabtree Meadow	13.0
4	Lone Pine Cottonwood PH	8.8
5	Tunnel RS	12.0
6	Wet Meadow	25.0
7	Atwell	25.0
8	Hockett Meadow	30.3
11	Hossack	30.5
12	Quaking Aspen	34.0
13	Monache Meadow	14.0
14	Haiwee	6.5
16	Round Meadow	19.0
17	Kern Int 3	25.1
18	Johnsondale	30.4
19	Doublebunk Meadow	31.0
21	Posey 3E	15.5
22	Woody	5.1
23	Glennville	8.6
25	Kern PH No. 3	14.5
26	Wofford Hgts	11.0
27	Onyx	6.2
28	Weldon 1 WSW	6.1
29	Isabella Dam	11.5
30	Loraine	7.6
32	Kern PH No. 1	3.5
33	Kern Canyon	2.7
34	Arvin	.9
35	Bakersfield 1W	1.4
36	Bakersfield WB AP	1.6
46	Rodgers Camp	28.0
47	Eagle Cr	26.5
48	Uhl RS	15.2
52	Keene	4.5
53	Videtta Meadow	17.0
55	Lone Pine 5 NW	6.4
56	Lone Pine	5.0
57	Chagoopa	14.0
58	Mineral King	26.0
59	Lone Pine 13 SE	9.3
60	Haiwee Res	6.6
61	Portuguese Meadow	29.0
62	Greenhorn Mtn	23.4
63	Borel PH	10.1
64	Kern Int No. 1	7.6
65	DiGiorgic	1.1
66	Magunden	1.5

KERN RIVER, CALIFORNIA

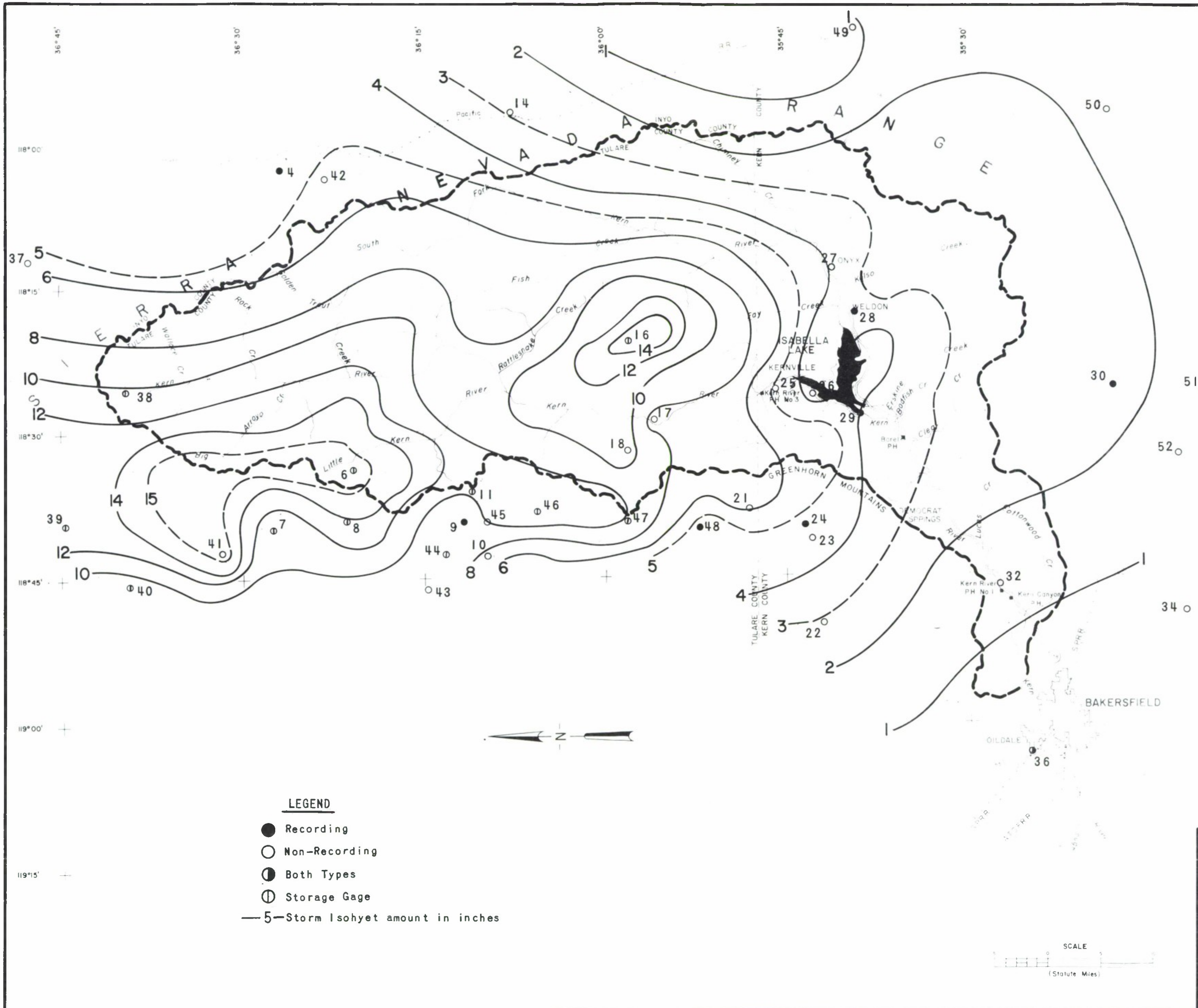
ISOHYETAL MAP
2-6 DECEMBER 1966

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared RCK
Drawn C.A.P.

Date: JANUARY 1979

CHART 6



NO.	DESCRIPTION	STORM AMOUNT (Inches)
4	Lone Pine Cottonwood PH	4.7
6	Wet Meadow	15.1
7	Atwell	10.3
8	Hockett Meadow	13.8
9	Springville Tule Hdwks	8.7
10	Springville 7 ENE	6.1
11	Hossack	11.2
14	Haiwee	2.9
16	Round Meadow	14.7
17	Kern Int 3	7.6
18	Johnsondale	11.1
21	Posey 3E	6.0
22	Woody	2.8
23	Glennville	4.5
24	Glennville Fulton RS	4.5
25	Kern PH No. 3	4.7
26	Wofford Hgts	3.8
27	Onyx	3.9
28	Weldon 1 WSW	3.3
29	Isabella Dam	4.0
30	Loraine	2.3
32	Kern PH No. 1	1.7
34	Arvin	.7
36	Bakersfield WB AP	.5
37	Independence	5.7
38	Tyndall Cr	10.1
39	Mitchell Meadow	12.9
40	Beartrap Meadow	8.6
41	Giant Forest	15.7
42	Cottonwood Gate	5.1
43	Milo 5 NE	7.9
44	Mountain Home	9.4
45	Camp Wishon	10.0
46	Rodgers Camp	11.1
47	Eagle Cr	9.9
48	Uhl RS	4.6
49	Inyokern	.7
50	Cantil	1.5
51	Tehachapi AP	1.4
52	Keene	1.9

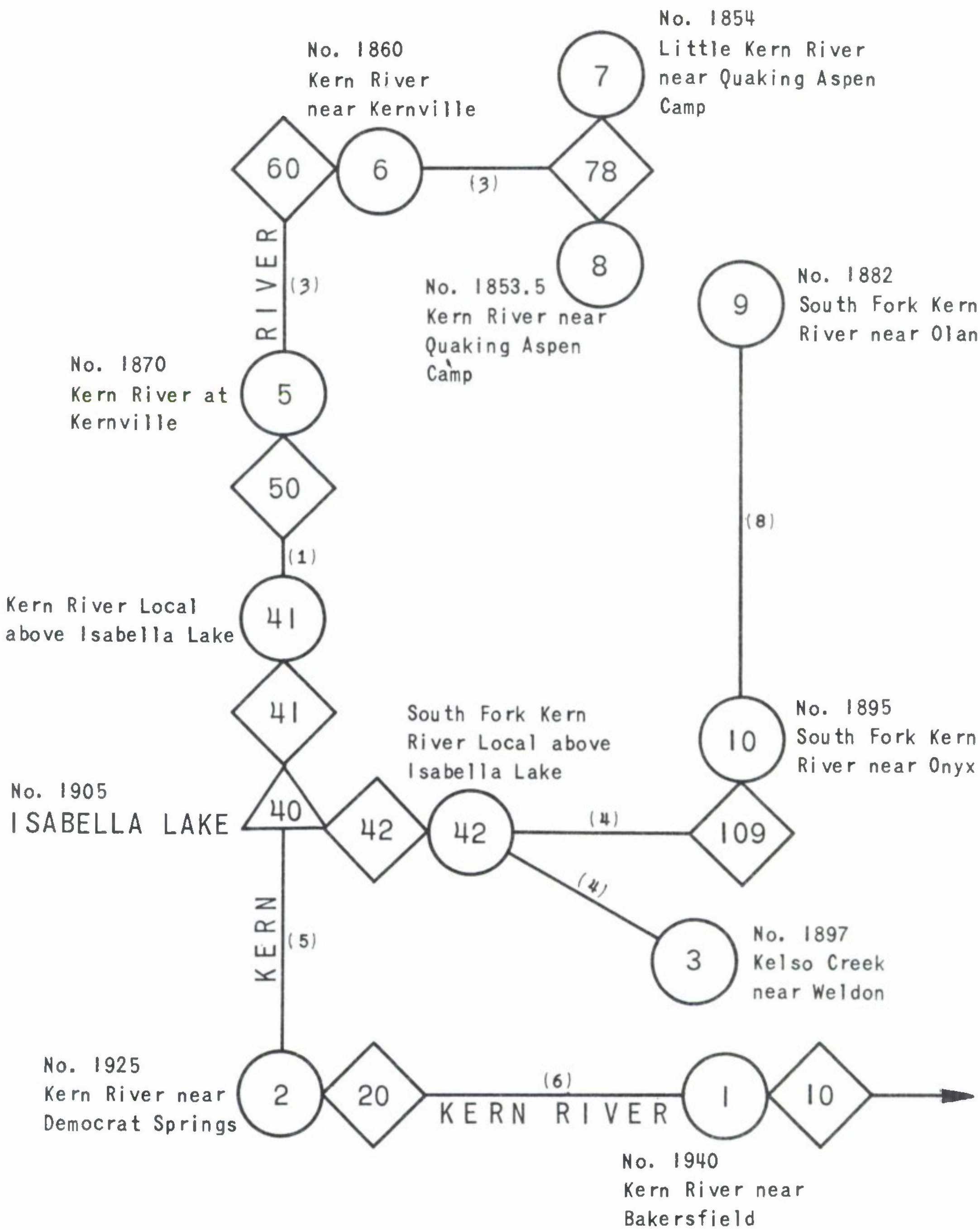
KERN RIVER, CALIFORNIA

ISOHYETAL MAP
24-26 JANUARY 1969

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

CHART 7



LEGEND

△ Lake

○ Subarea

◇ Routing and Combination Points

(4) Tatum Routing Steps between Index Points (2 hour time interval)

KERN RIVER, CALIFORNIA

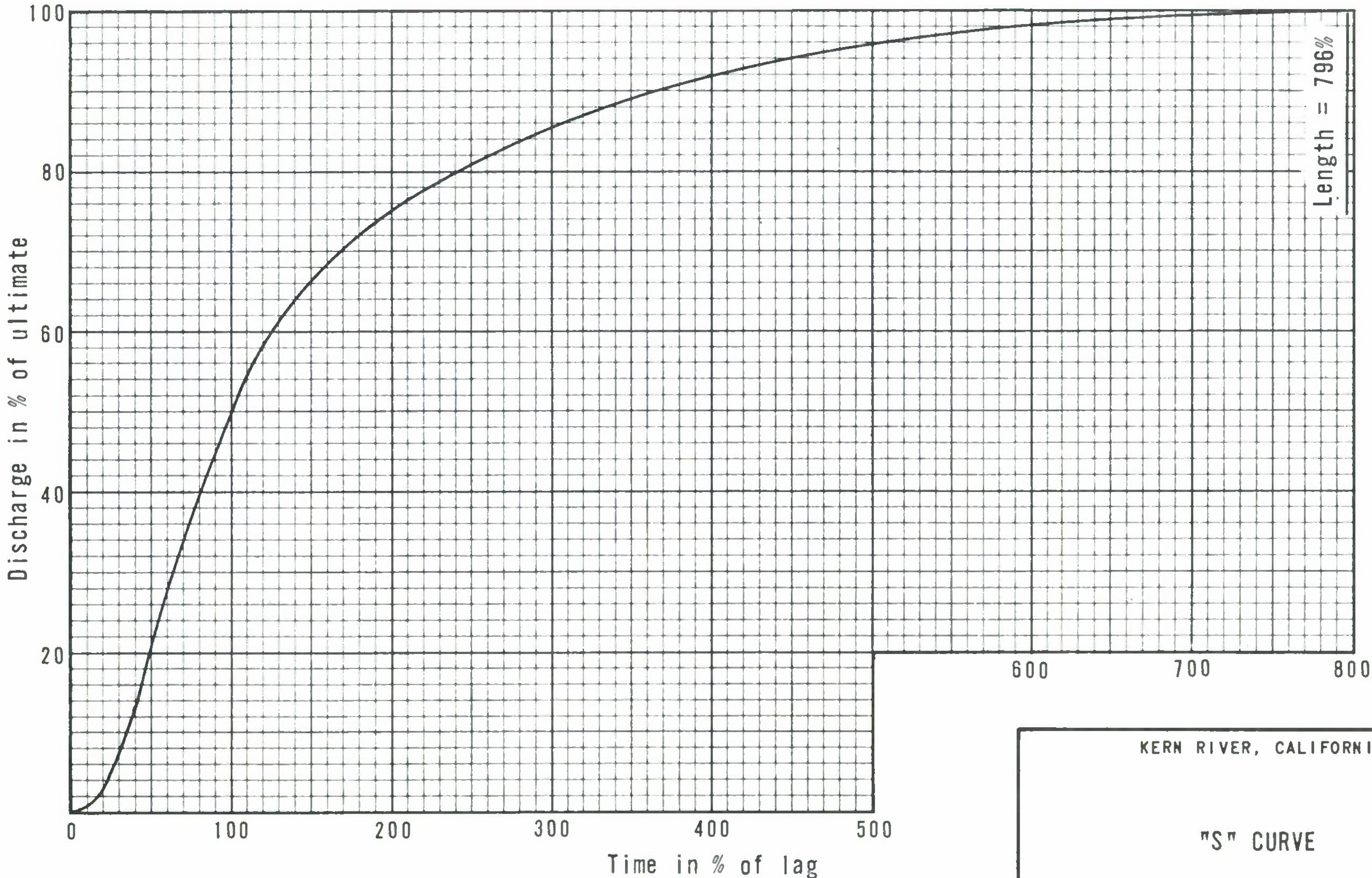
ROUTING DIAGRAM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.

Date: JANUARY 1979

CHART 8

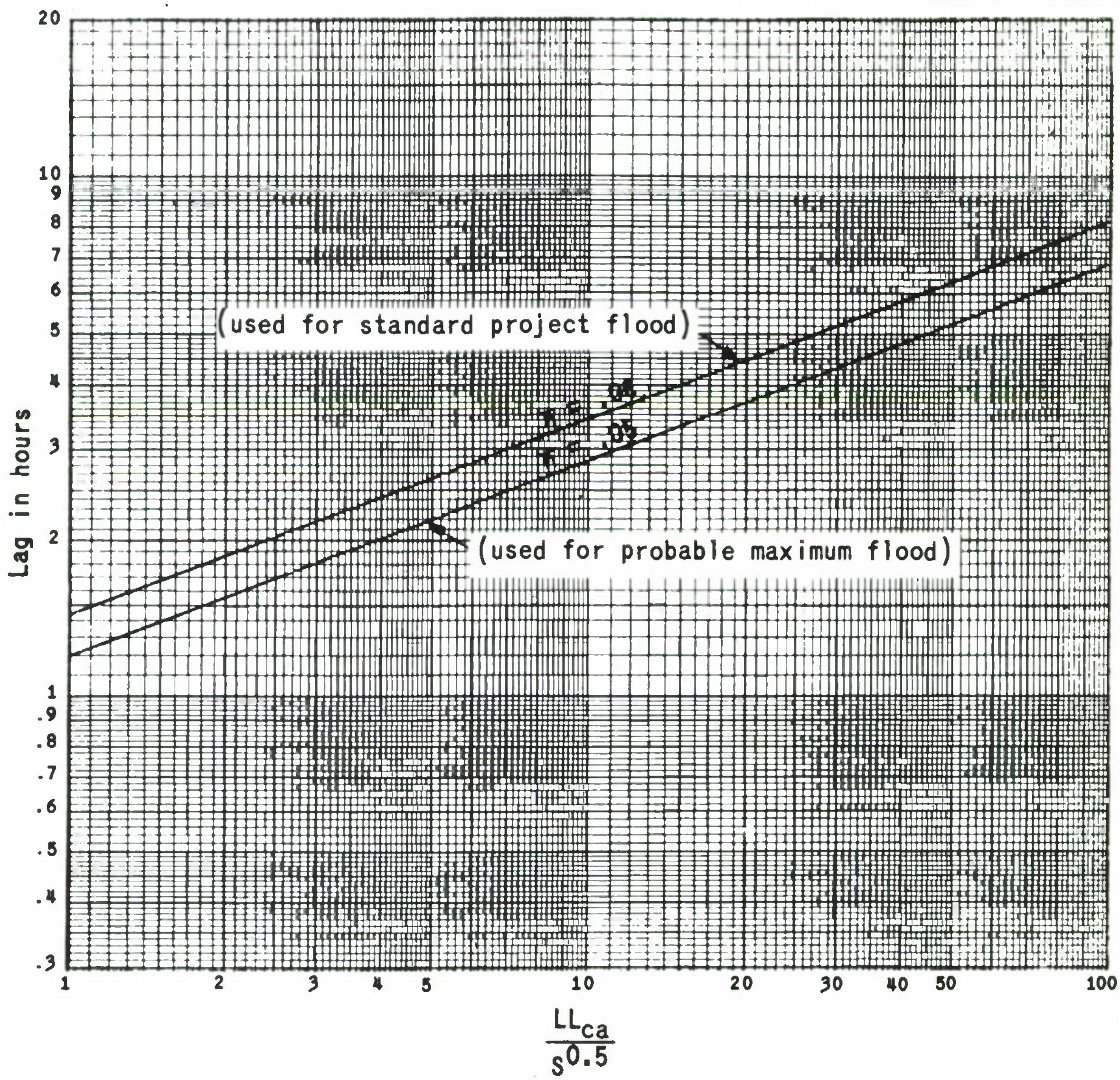


KERN RIVER, CALIFORNIA

"S" CURVE

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: M.A.S.
Drawn: C.A.P.
Date: JANUARY 1979



TERMINOLOGY

L - Length of longest watercourse.

L_{ca} - Length along longest watercourse, measured upstream to point opposite center of area.

S - Overall slope of longest watercourse between headwater and collection point.

Lag - Elapsed time from beginning of unit precipitation to instant that summation hydrograph reaches 50% of ultimate discharge.

$\bar{n}$ - Basin factor representing basin shape, drainage pattern, and roughness of the stream beds.

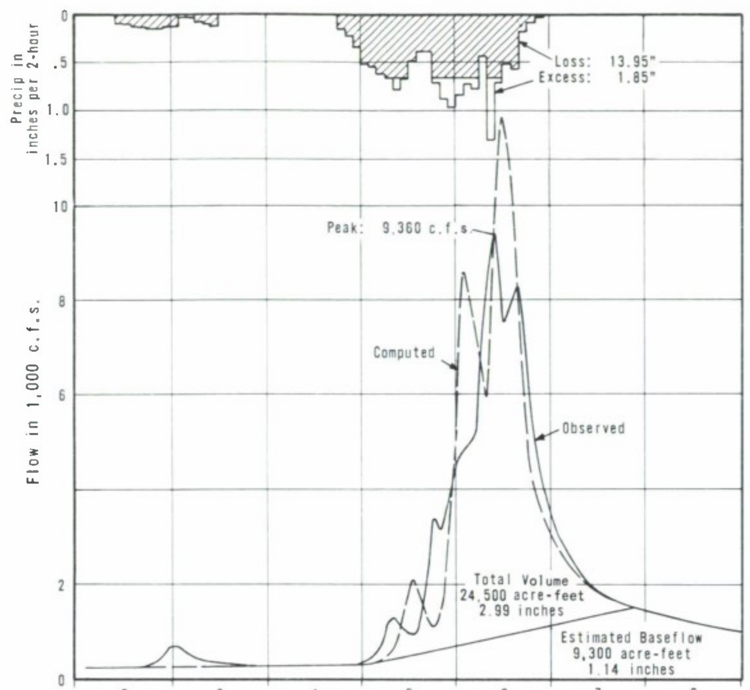
KERN RIVER, CALIFORNIA

LAG RELATIONSHIPS

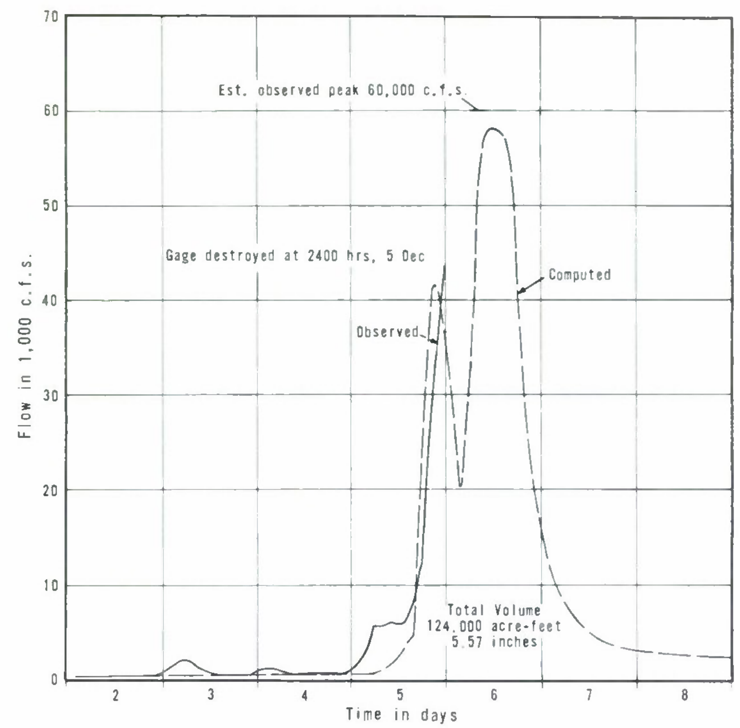
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: M.A.S.
Drawn: C.A.P.
Date: JANUARY 1979

CHART 10



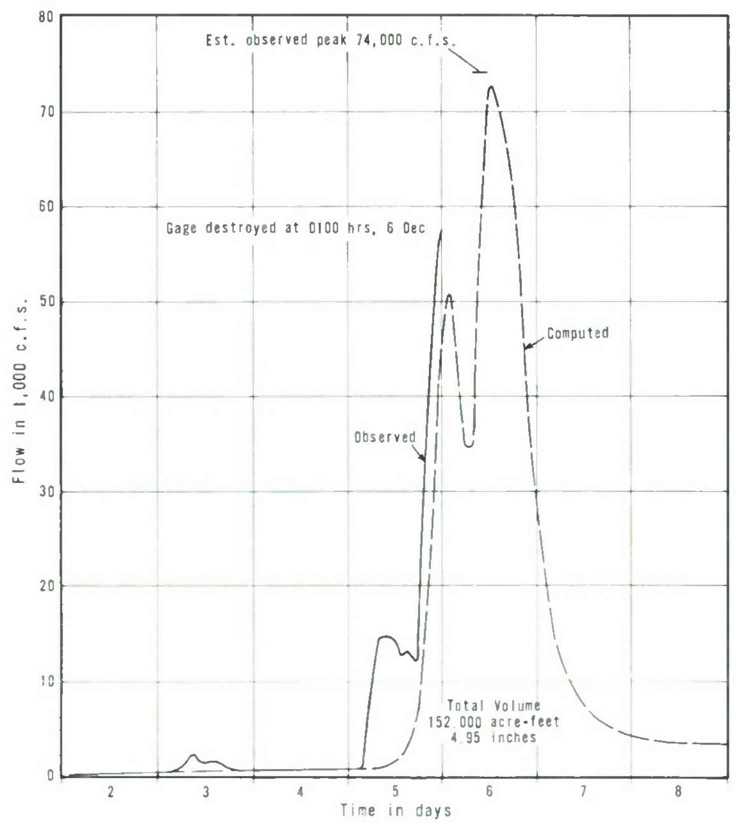
KERN RIVER NEAR QUAKING ASPEN CAMP
Contributing drainage area: 154 sq. mi.



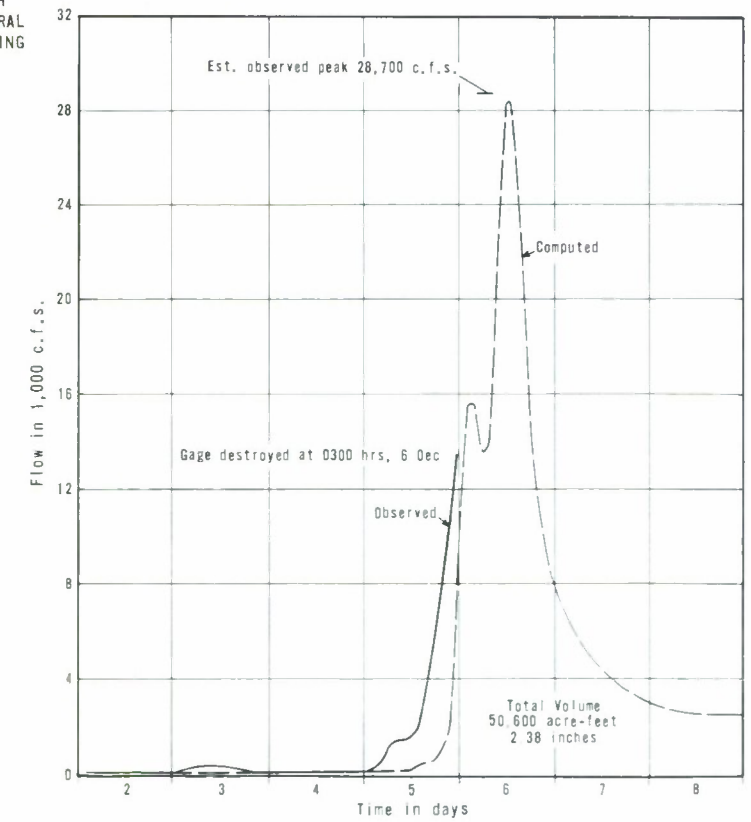
KERN RIVER NEAR KERNVILLE
Contributing drainage area: 419 sq. mi.

NOTE:

HYETOGRAPH AND BASEFLOW ARE NOT SHOWN BECAUSE HYDROGRAPH REPRESENTS RUNOFF FROM SEVERAL SUBAREAS COMBINED WITH ROUTING EFFECTS.



KERN RIVER AT KERNVILLE
Contributing drainage area: 577 sq. mi.



SOUTH FORK KERN RIVER NEAR ONYX
Contributing drainage area: 399 sq. mi.

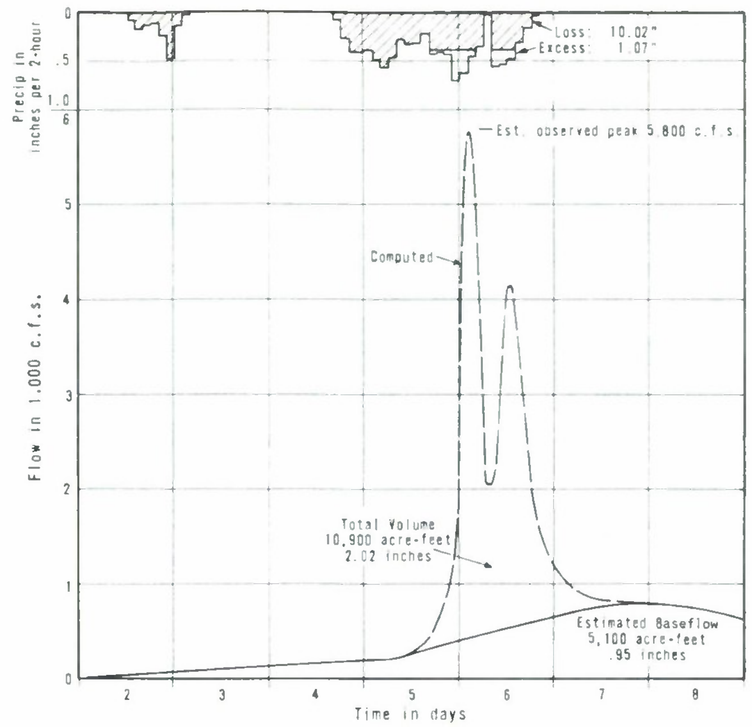
KERN RIVER, CALIFORNIA

DECEMBER 1966 FLOOD HYDROGRAPHS

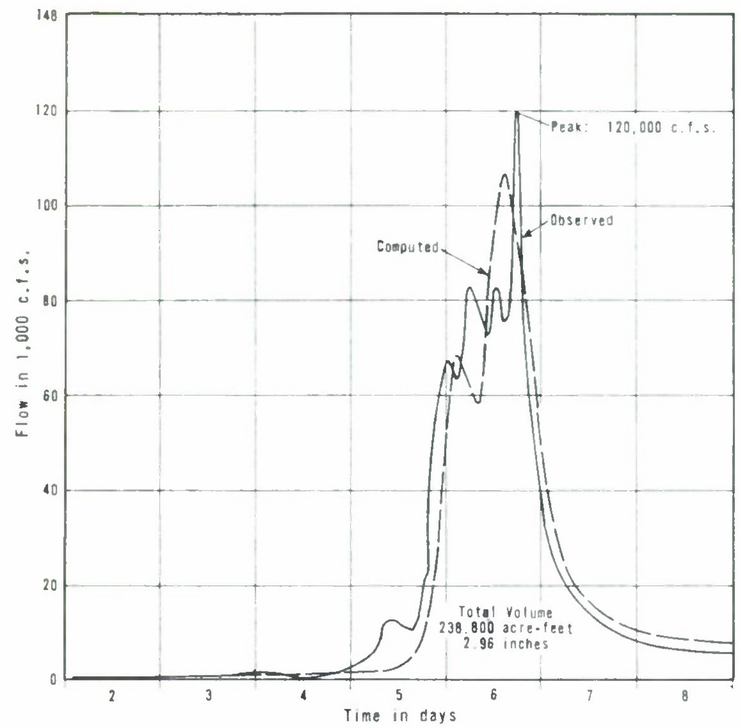
CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: C.A.P., R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

SHEET 1 OF 3 CHART 11

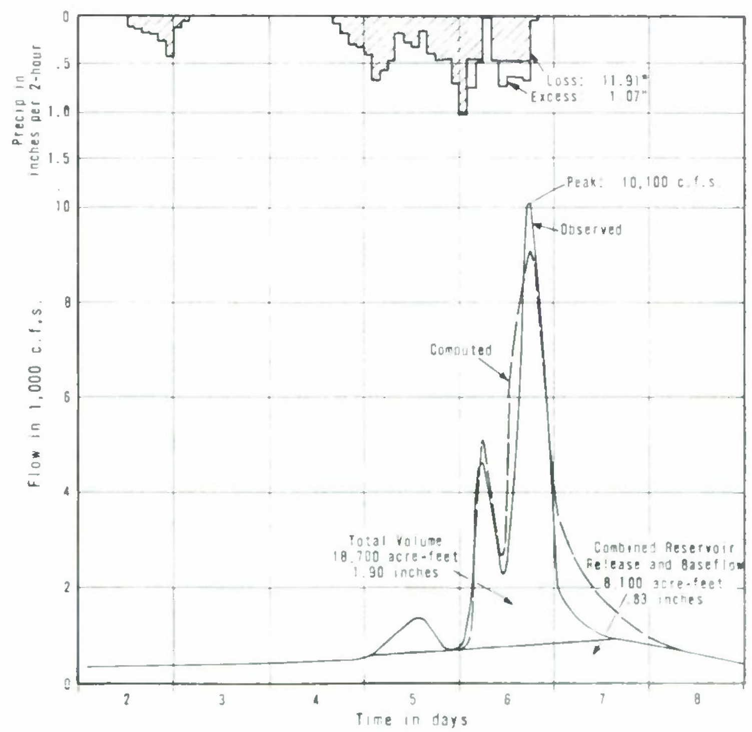


KELSO CREEK NEAR WELDON
Contributing drainage area: 101 sq. mi.

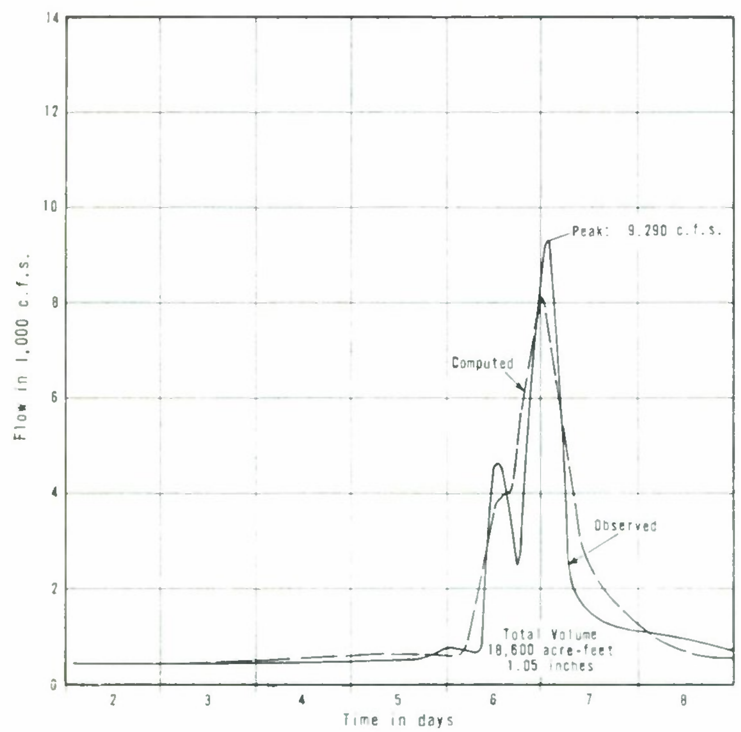


INFLOW TO ISABELLA LAKE
Contributing drainage area: 1,511 sq. mi.

NOTE:
HYETOGRAPH AND BASEFLOW ARE NOT SHOWN BECAUSE HYDROGRAPH REPRESENTS RUNOFF FROM SEVERAL SUBAREAS COMBINED WITH ROUTING EFFECTS.



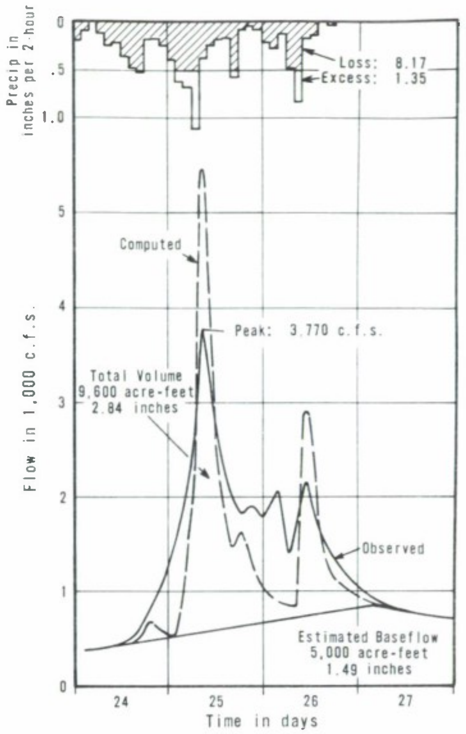
KERN RIVER NEAR DEMOCRAT SPRINGS
Contributing drainage area (below Isabella Dam): 184 sq. mi.



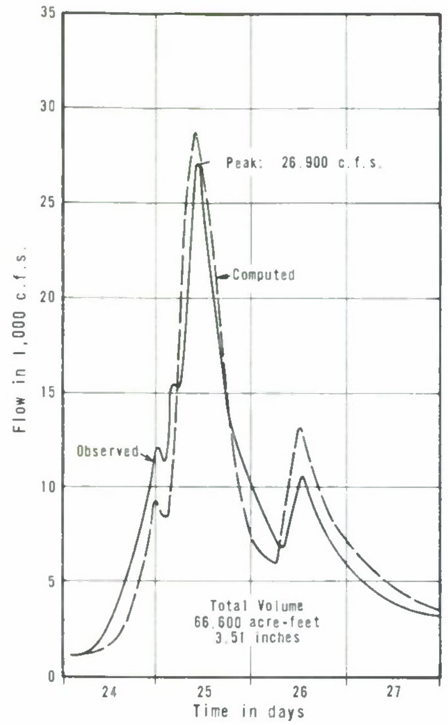
KERN RIVER NEAR BAKERSFIELD
Contributing drainage area (below Isabella Dam): 333 sq. mi.

KERN RIVER, CALIFORNIA	
DECEMBER 1966 FLOOD HYDROGRAPHS	
CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA	
Prepared: C.A.P., R.C.K. Drawn: C.A.P.	Date: JANUARY 1979

SHEET 2 OF 3 CHART 11

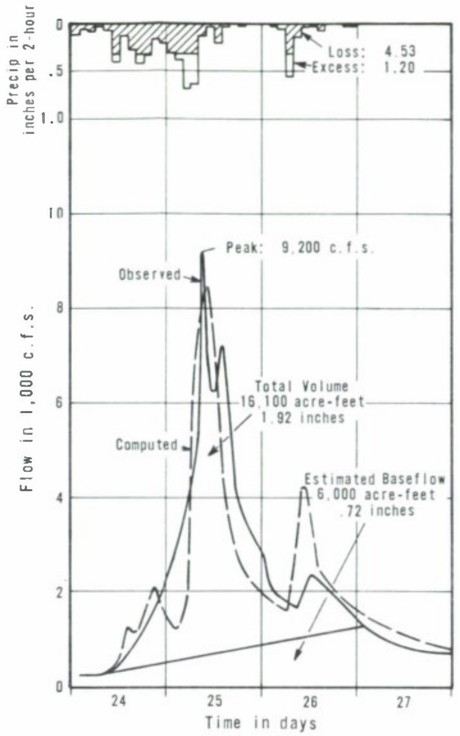


KERN RIVER NEAR QUAKING ASPEN CAMP
Contributing drainage area: 63.0 sq. mi.

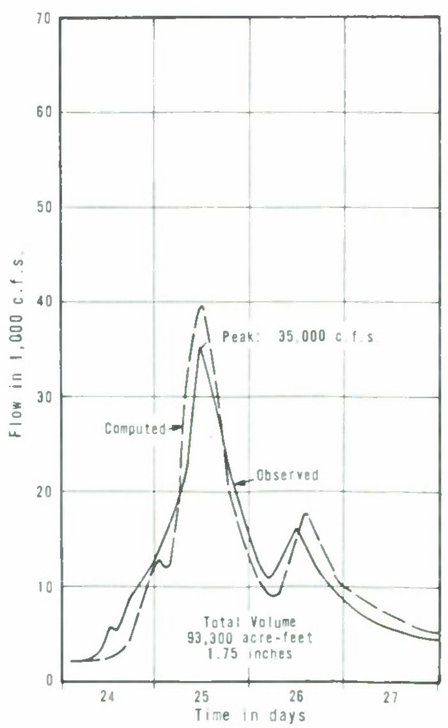


KERN RIVER AT KERNVILLE
Contributing drainage area: 356 sq. mi.

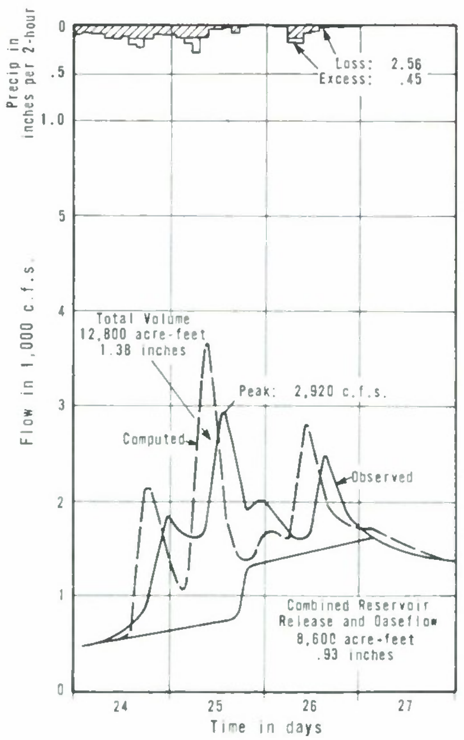
NOTE:
HYETOGRAPH AND BASEFLOW ARE NOT SHOWN BECAUSE HYDROGRAPH REPRESENTS RUNOFF FROM SEVERAL SUBAREAS COMBINED WITH ROUTING EFFECTS.



SOUTH FORK KERN RIVER NEAR ONYX
Contributing drainage area: 157 sq. mi.



INFLOW TO ISABELLA LAKE
Contributing drainage area: 1000 sq. mi.



KERN RIVER NEAR DEMOCRAT SPRINGS
Contributing drainage area (below Isabella Dam): 174 sq. mi.

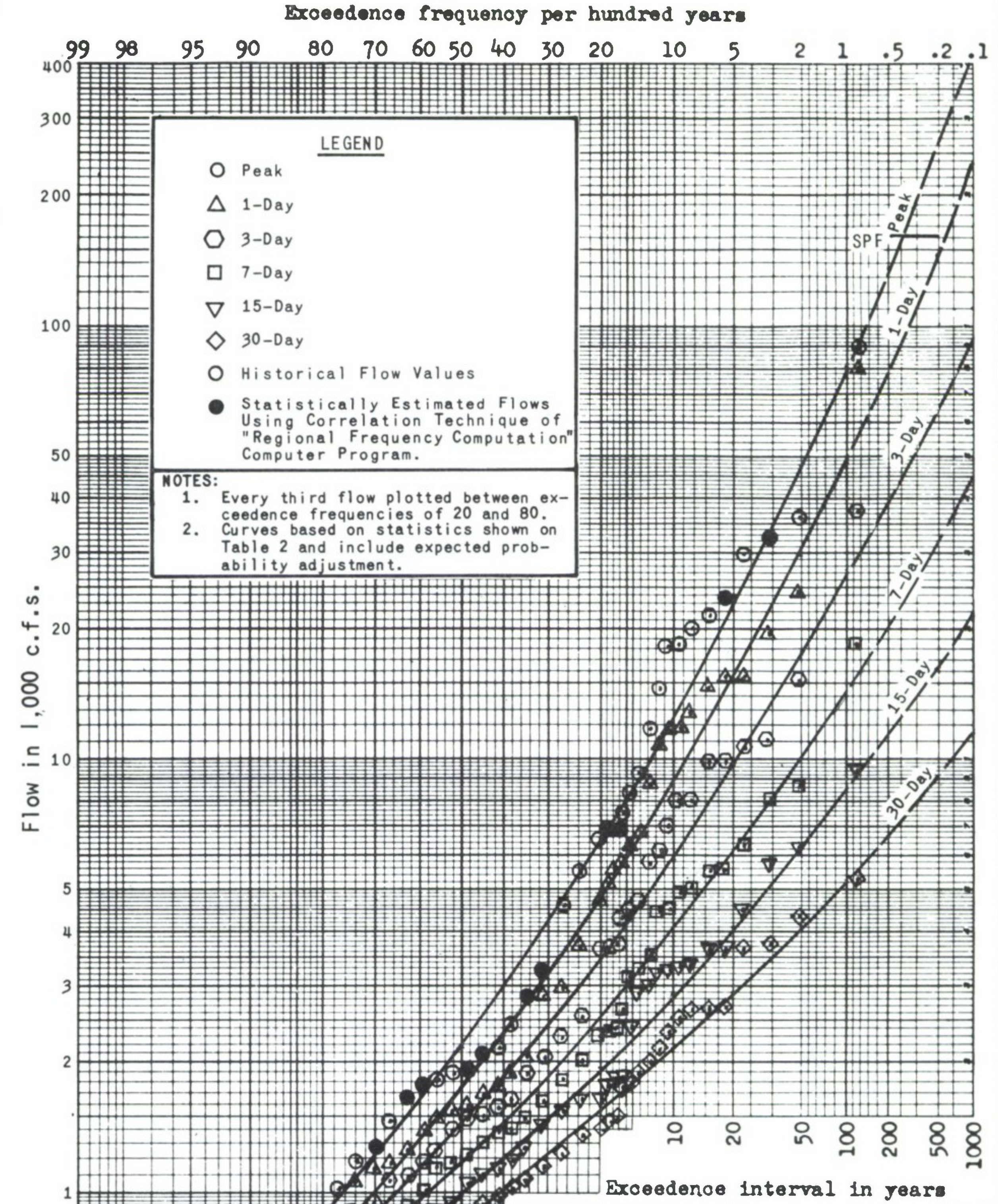
KERN RIVER, CALIFORNIA

JANUARY 1969 FLOOD HYDROGRAPHS

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: C.A.P., R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

SHEET 3 OF 3 CHART 11



KERN RIVER, CALIFORNIA

UNREGULATED FLOW FREQUENCY
(OCTOBER THRU MARCH RAINFLOOD)

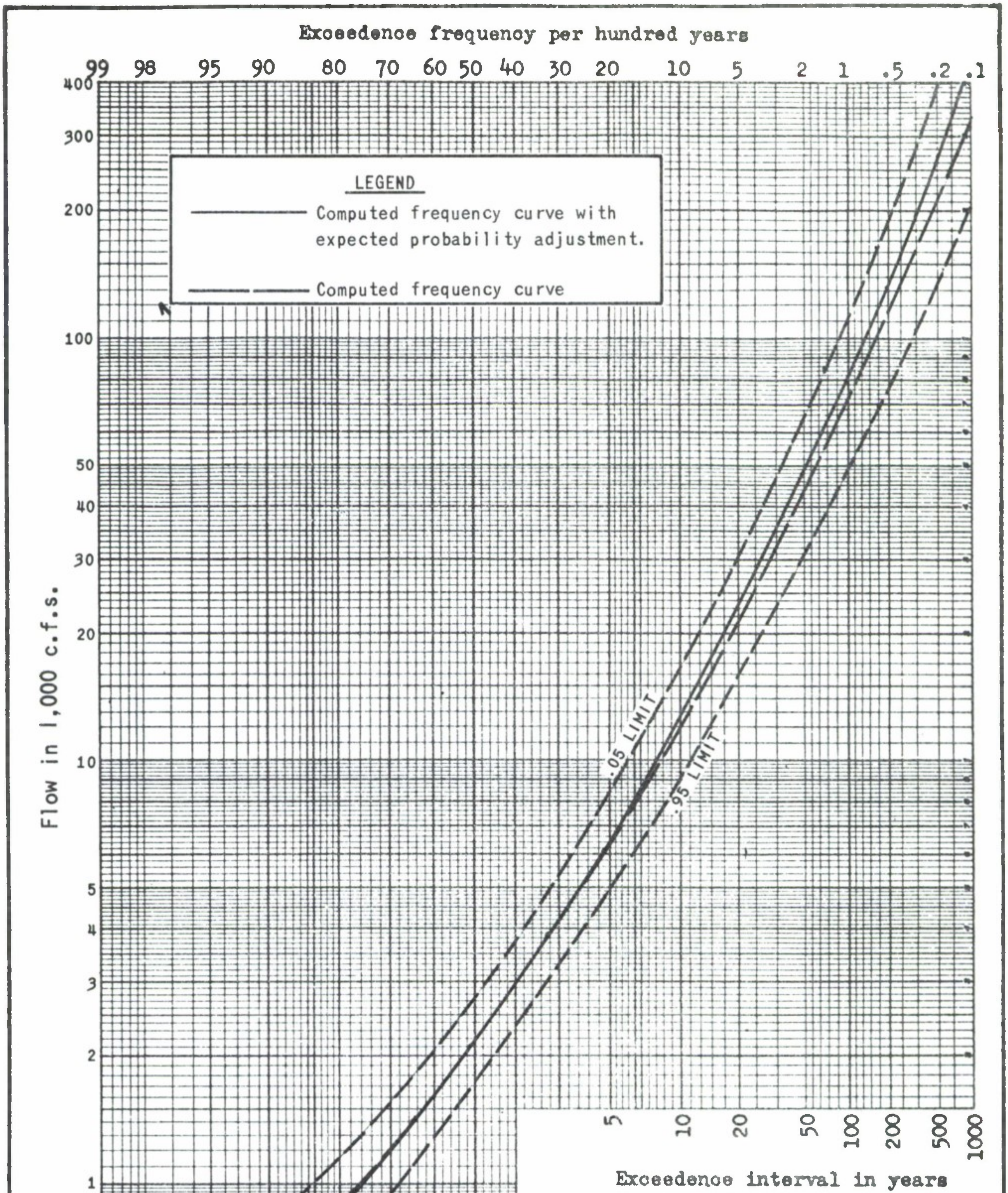
KERN RIVER NEAR BAKERSFIELD

Period of record: 1894-1976

Drainage area: 2407 sq. mi.

Corps of Engineers, Sacramento, Calif.

Prepared: C.A.P., R.C.K. Date: JANUARY 1979



KERN RIVER, CALIFORNIA

UNREGULATED
PEAK FLOW FREQUENCY
(OCTOBER THRU MARCH RAINFLOOD)

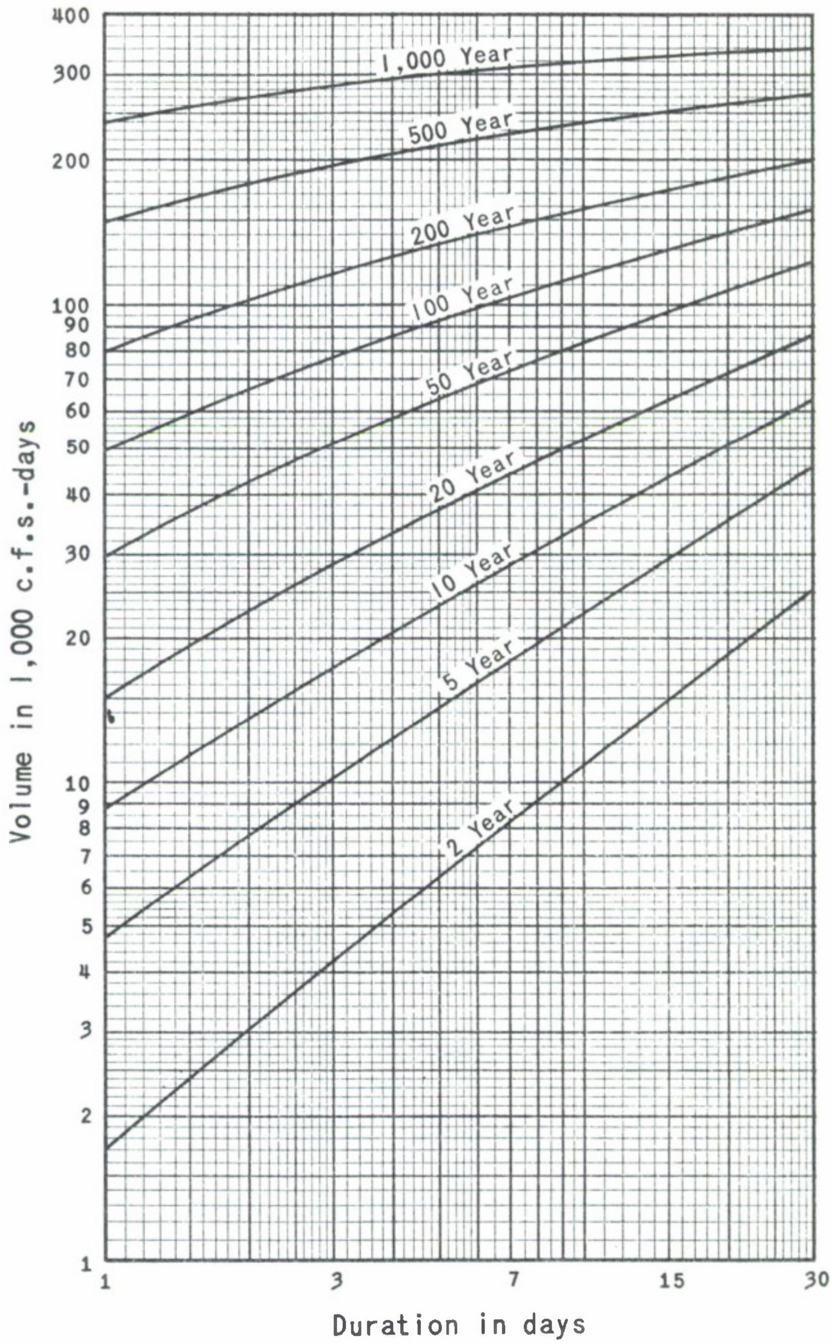
KERN RIVER NEAR BAKERSFIELD

Drainage area: 2407 sq. mi.

Corps of Engineers, Sacramento, Calif.

Prepared: C.A.P., R.C.K. Date: JANUARY 1979

CHART 13



KERN RIVER, CALIFORNIA

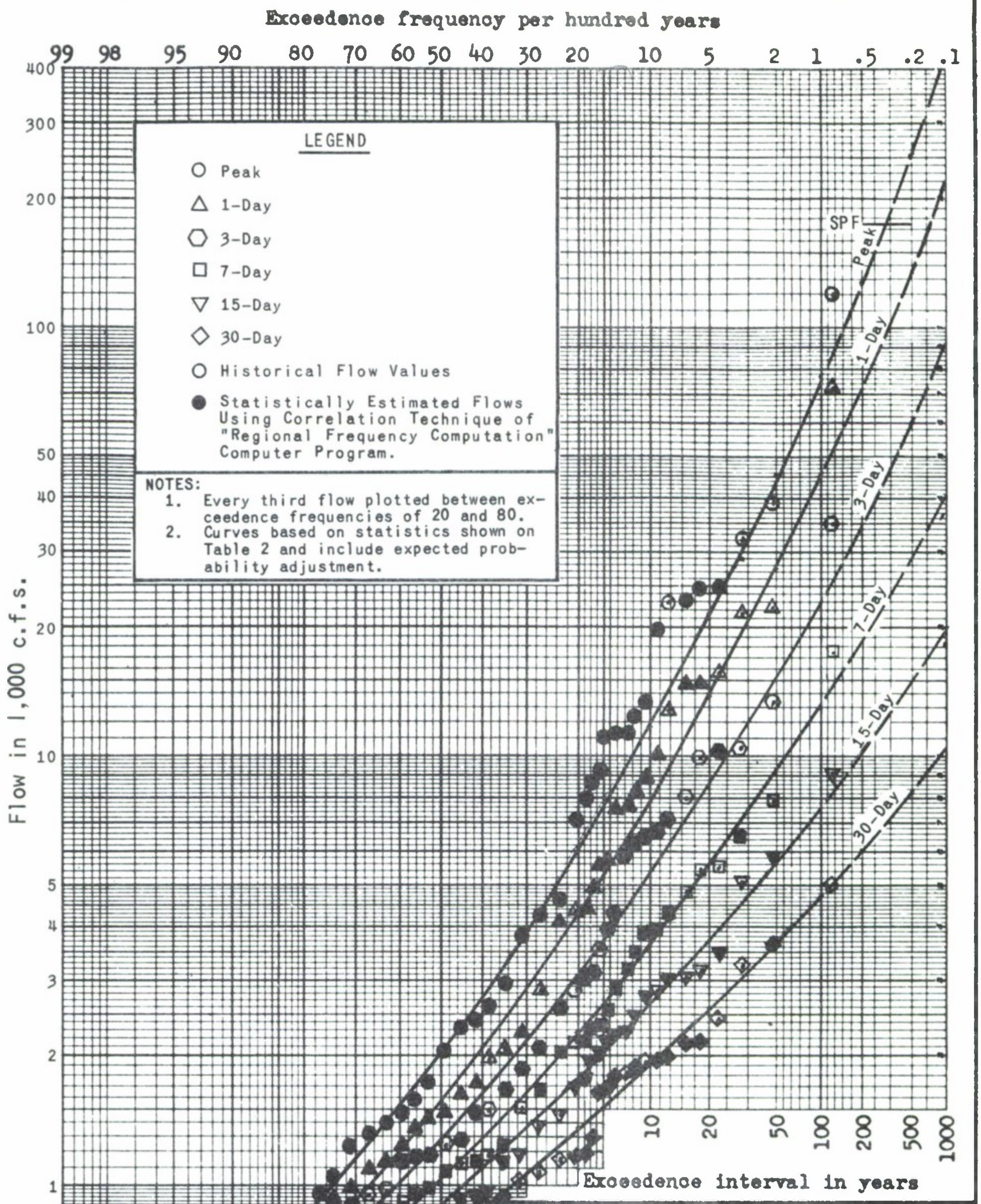
UNREGULATED VOLUME - DURATION
(OCTOBER THRU MARCH RAINFLOOD)

KERN RIVER NEAR BAKERSFIELD

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K. Date: JANUARY 1979
Drawn: C.A.P.

CHART 14



Period of record: 1946-1976

Drainage Area: 2074 sq. mi.

KERN RIVER, CALIFORNIA

UNREGULATED FLOW FREQUENCY
(OCTOBER THRU MARCH RAINFLOOD)

ISABELLA INFLOW

Corps of Engineers, Sacramento, Calif.

Prepared: C.A.P.,R.C.K. Date: JANUARY 1979

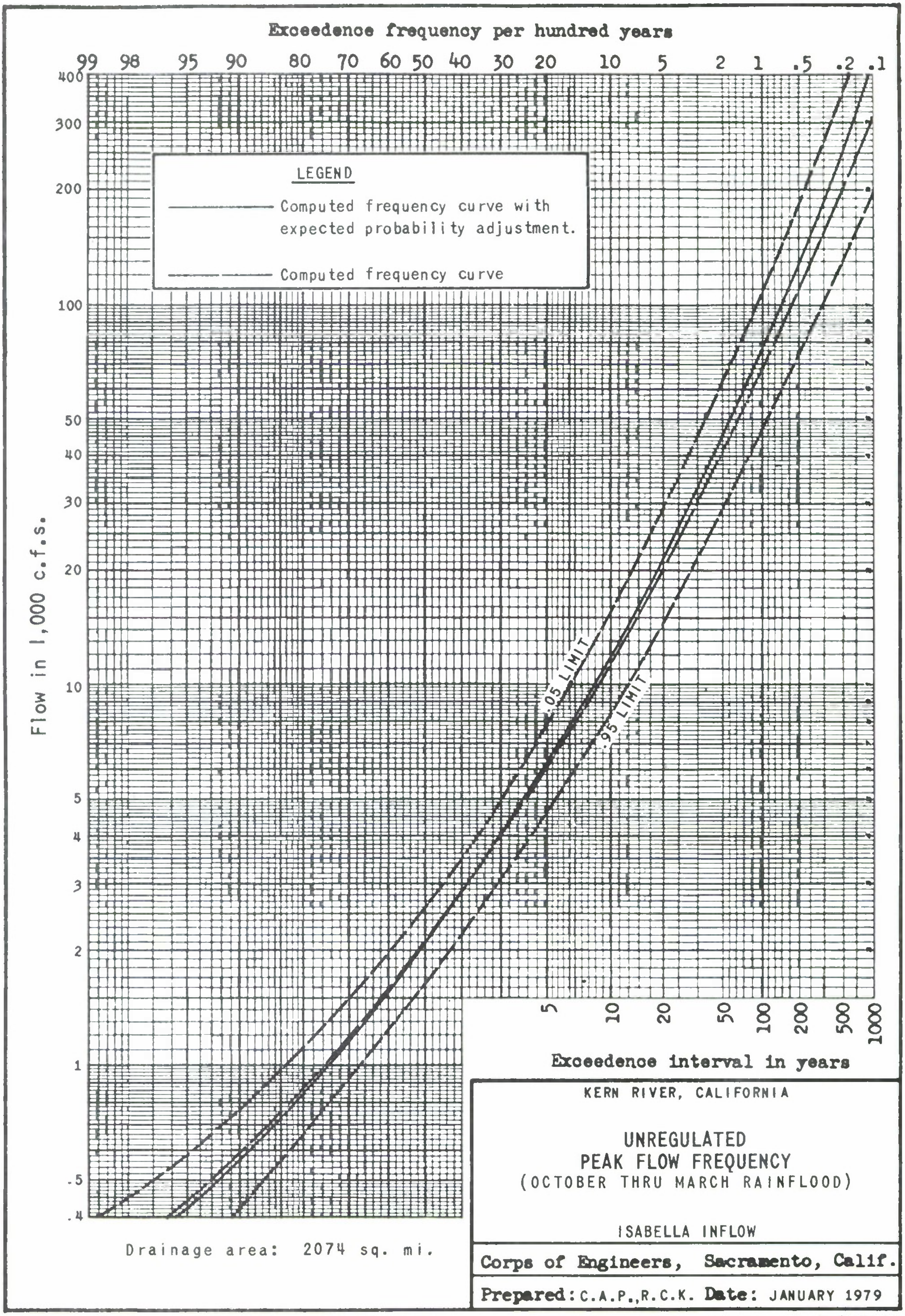
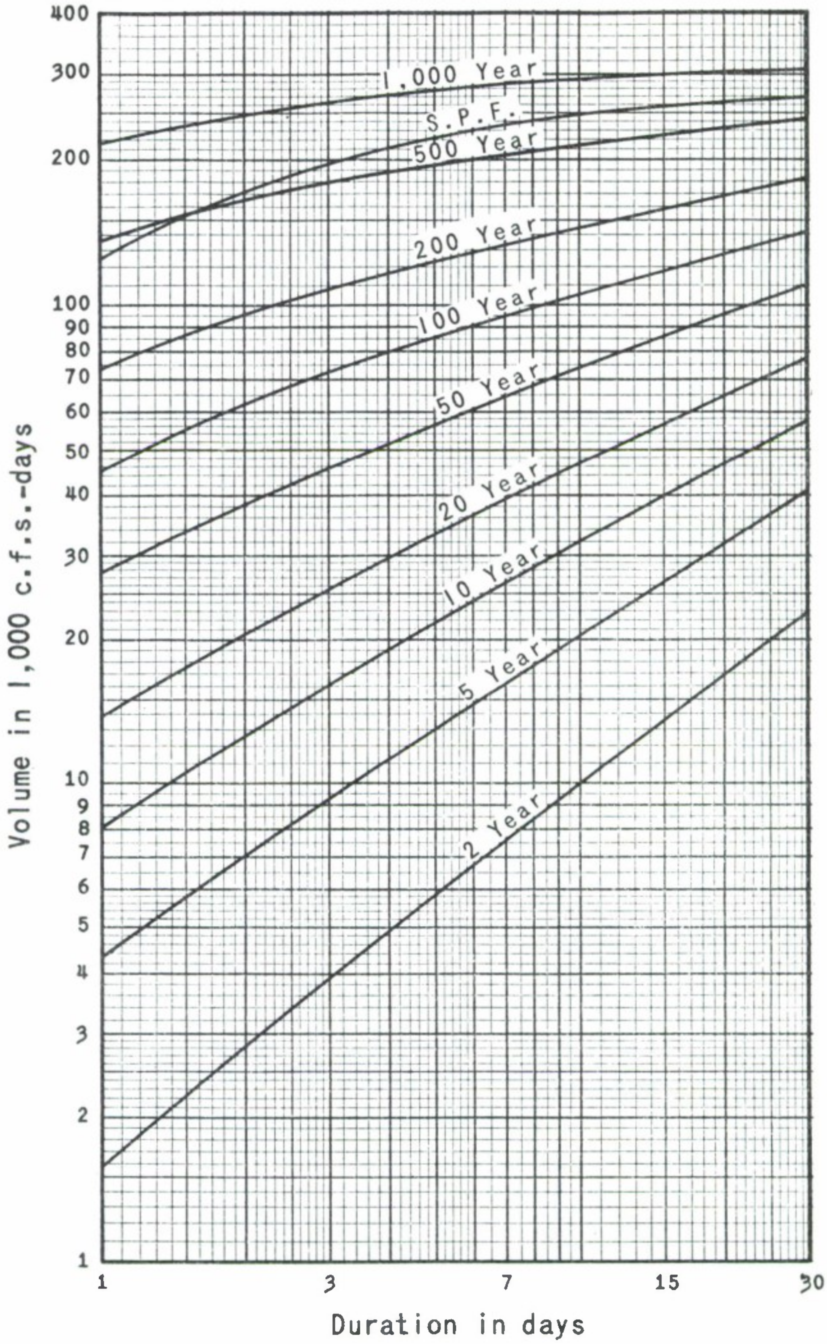

Exceedence frequency per hundred years
99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 .5 .2 .1
400 300 200 100 50 40 30 20 10 5 4 3 2 1 .5 .4
Flow in 1,000 c.f.s.
LEGEND
Computed frequency curve with expected probability adjustment.
Computed frequency curve
.05 LIMIT
.95 LIMIT
5 10 20 50 100 200 500 1000
Exceedence interval in years
Drainage area: 2074 sq. mi.
KERN RIVER, CALIFORNIA
UNREGULATED
PEAK FLOW FREQUENCY
(OCTOBER THRU MARCH RAINFLOOD)
ISABELLA INFLOW
Corps of Engineers, Sacramento, Calif.
Prepared: C.A.P., R.C.K. Date: JANUARY 1979

CHART 16



KERN RIVER, CALIFORNIA

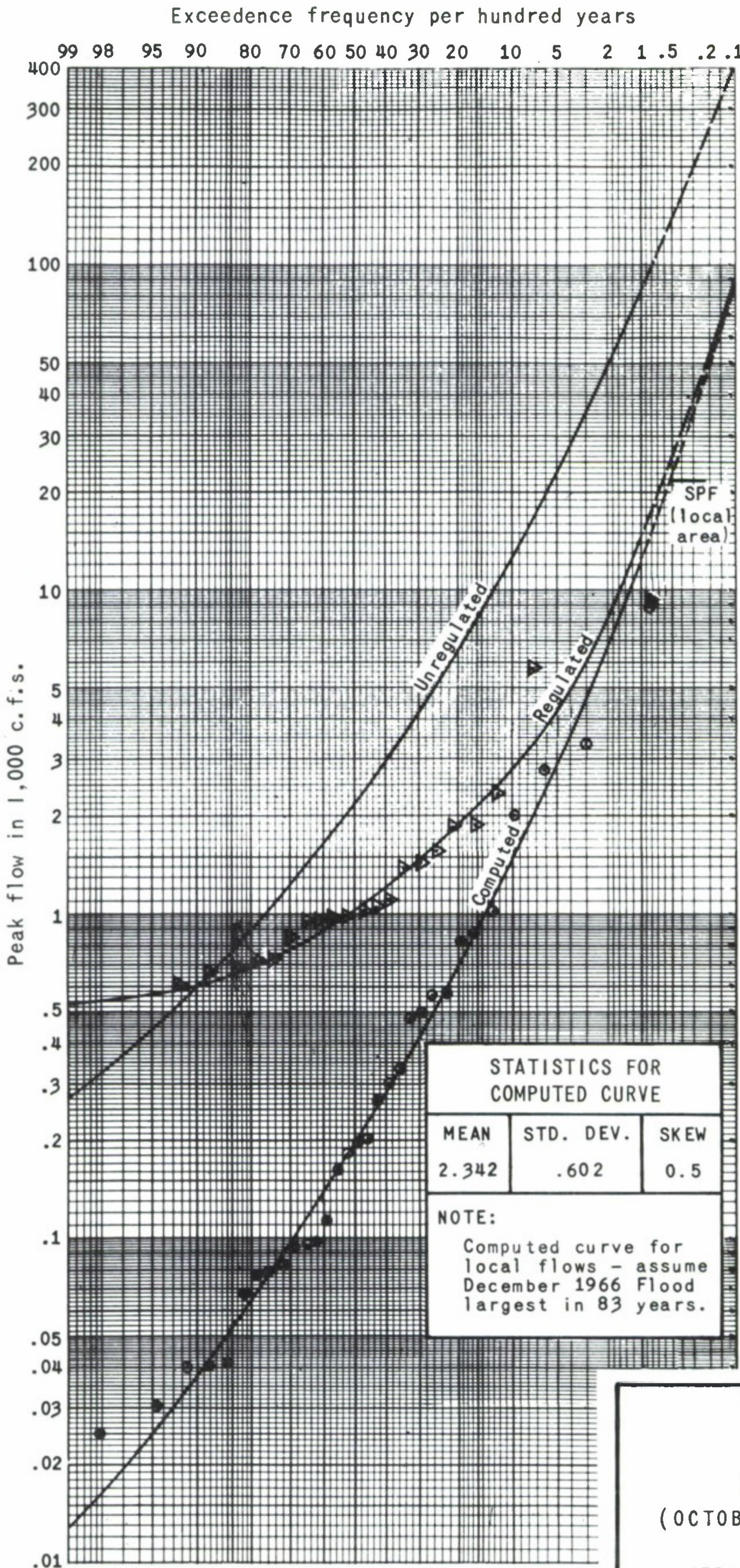
UNREGULATED VOLUME - DURATION
(OCTOBER THRU MARCH RAINFLOOD)

ISABELLA INFLOW

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

CHART 17



LEGEND

△ Historical daily flows at Bakersfield (1955-1976).

▲ Dec 1966 peak flow at Bakersfield - plotted as largest in 83 years of record.

⊙ Local peak flows at Bakersfield (1946-1976).

● Statistically estimated flows using correlation technique of "Regional Frequency Computation" computer program.

KERN RIVER, CALIFORNIA

PEAK FLOW FREQUENCY

(OCTOBER THRU MARCH RAINFLOOD)

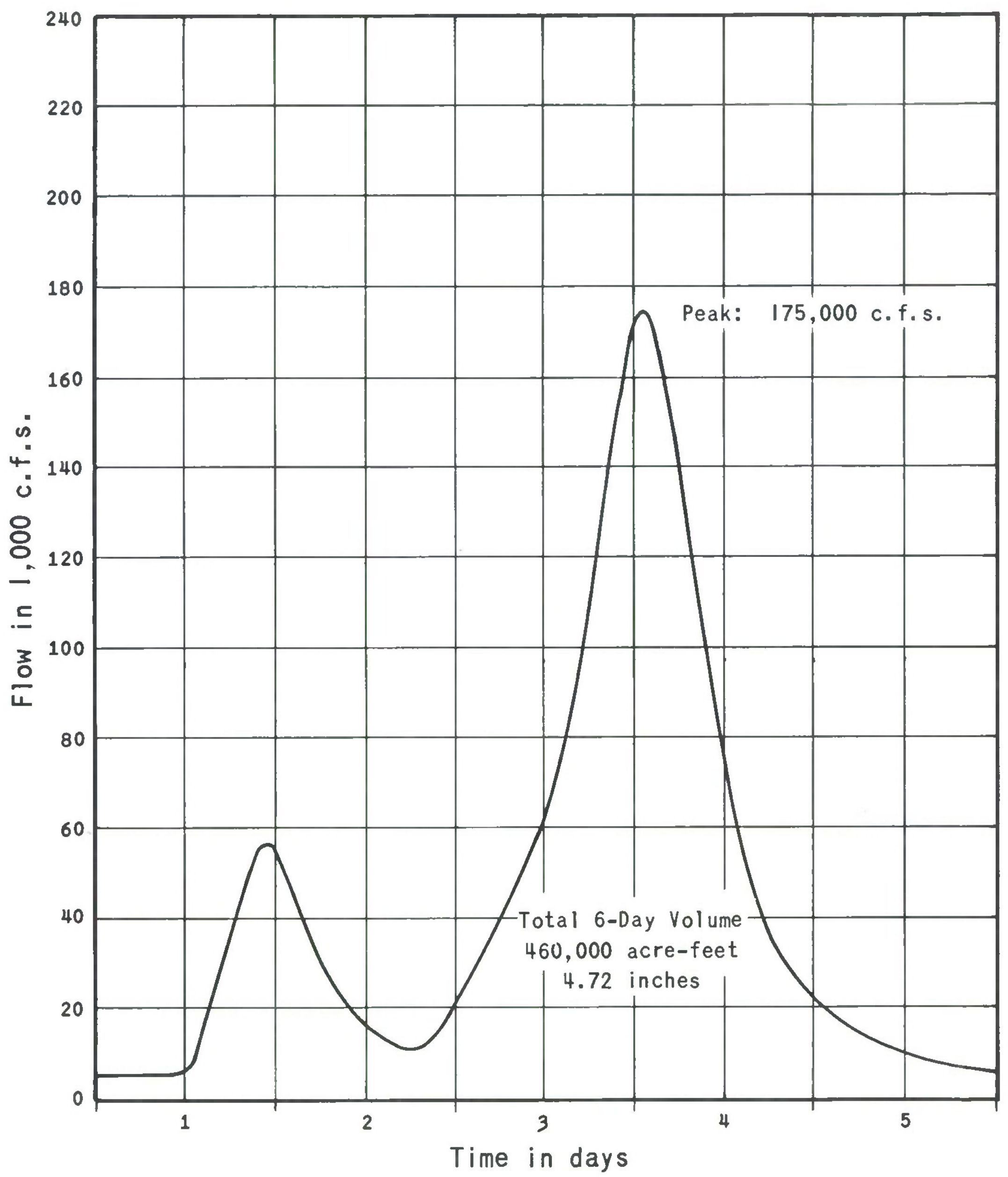
KERN RIVER NEAR BAKERSFIELD

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.

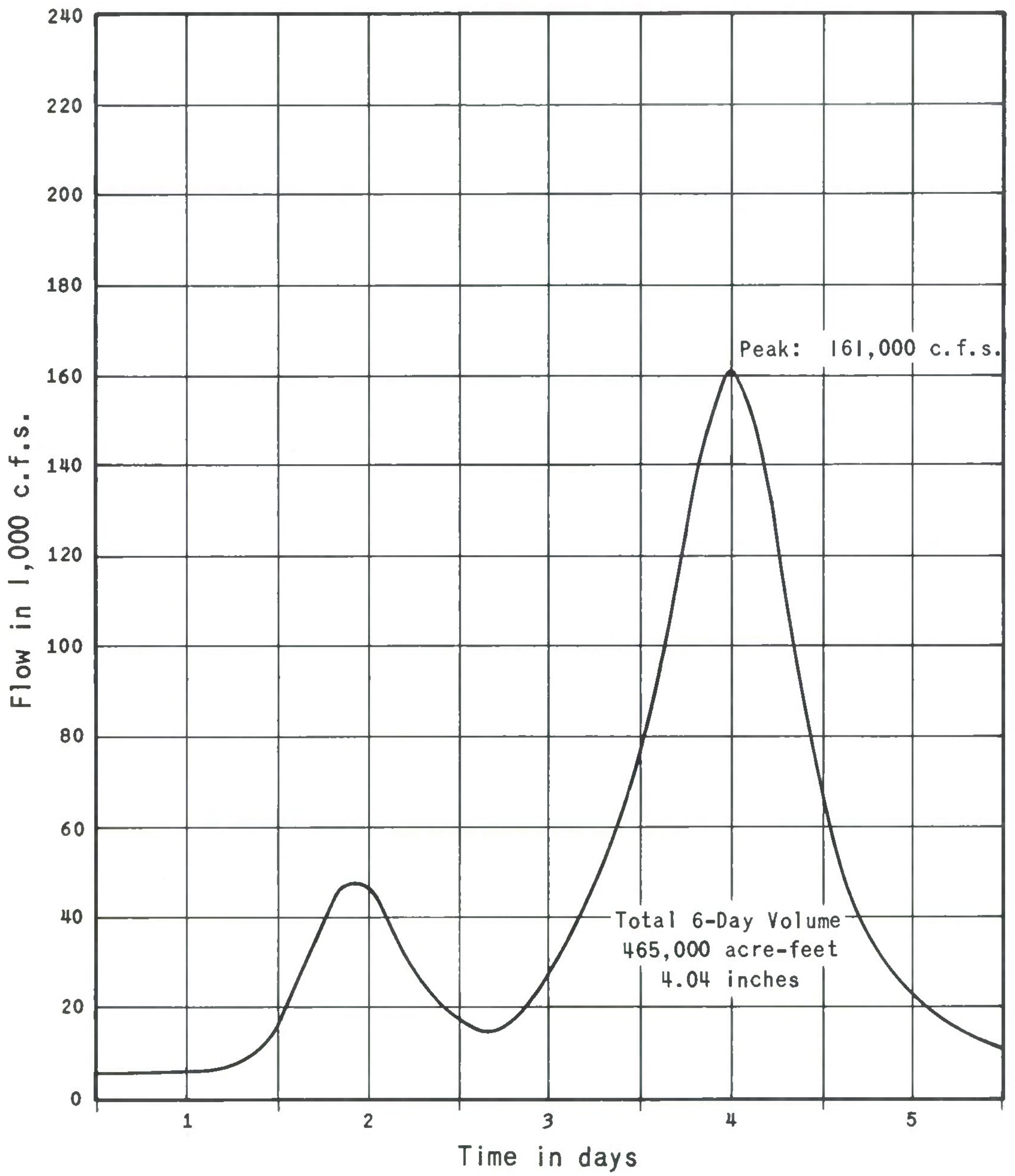
Date: JANUARY 1979

CHART 18



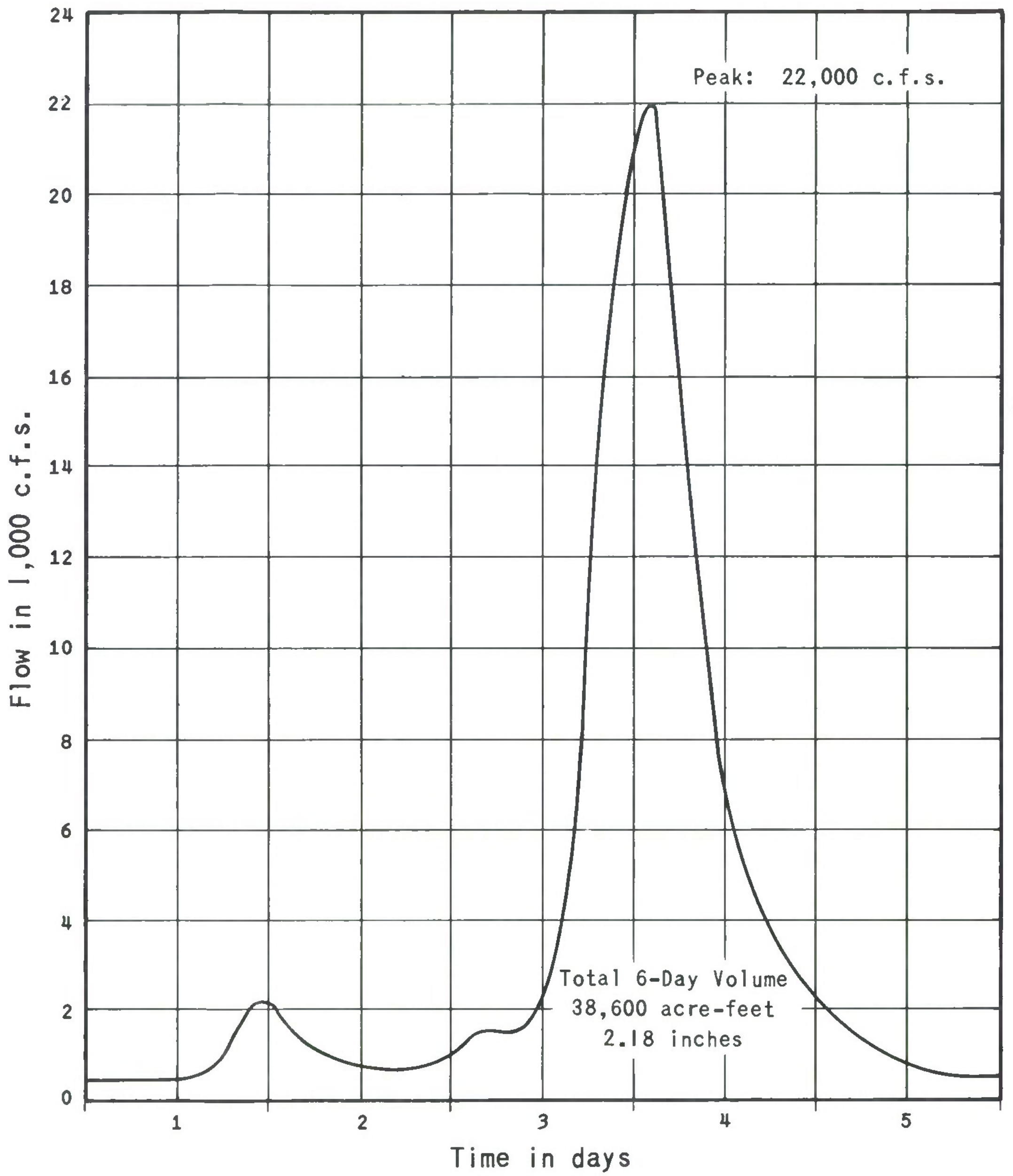
INFLOW TO ISABELLA LAKE

Contributing drainage area: 1,825 sq. mi.



KERN RIVER NEAR BAKERSFIELD
(UNREGULATED CONDITIONS)

Contributing drainage area: 2,158 sq. mi.



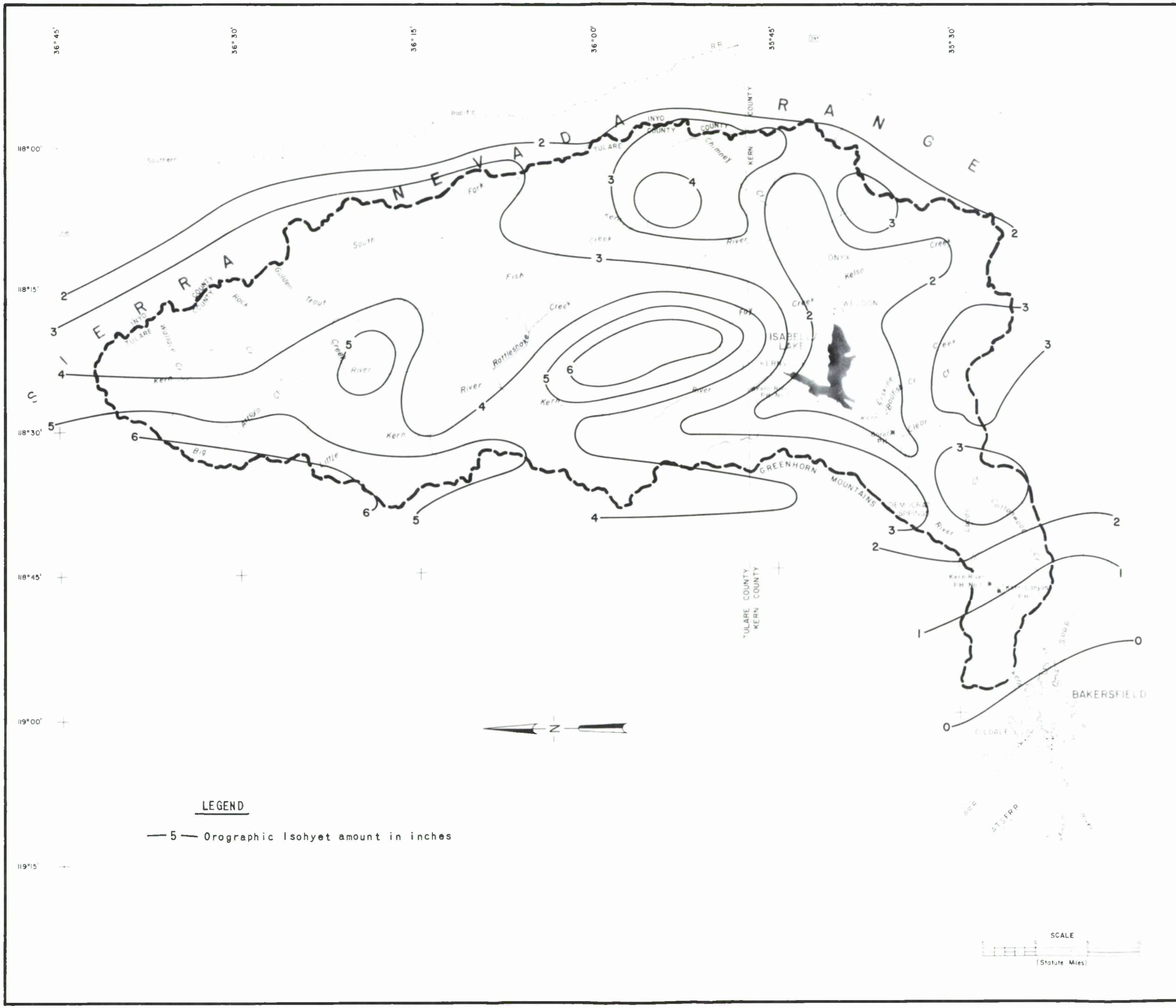
KERN RIVER NEAR BAKERSFIELD
(LOCAL AREA BELOW ISABELLA LAKE)

Contributing drainage area: 333 sq. mi.

NOTE:
Hyetographs and baseflow are not shown because Hydrographs represent runoff from several subareas combined with routing effects.

KERN RIVER, CALIFORNIA
STANDARD PROJECT FLOOD HYDROGRAPHS
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA
Prepared: C.A.P. Drawn: C.A.P. Date: JANUARY 1979

CHART 19



NOTE:

Indices based on U.S. Weather Bureau, Hydrometeorlogical Report No. 36, October 1961 with revisions of October 1969.

LEGEND

— 5 — Orographic Isohyet amount in inches

KERN RIVER, CALIFORNIA

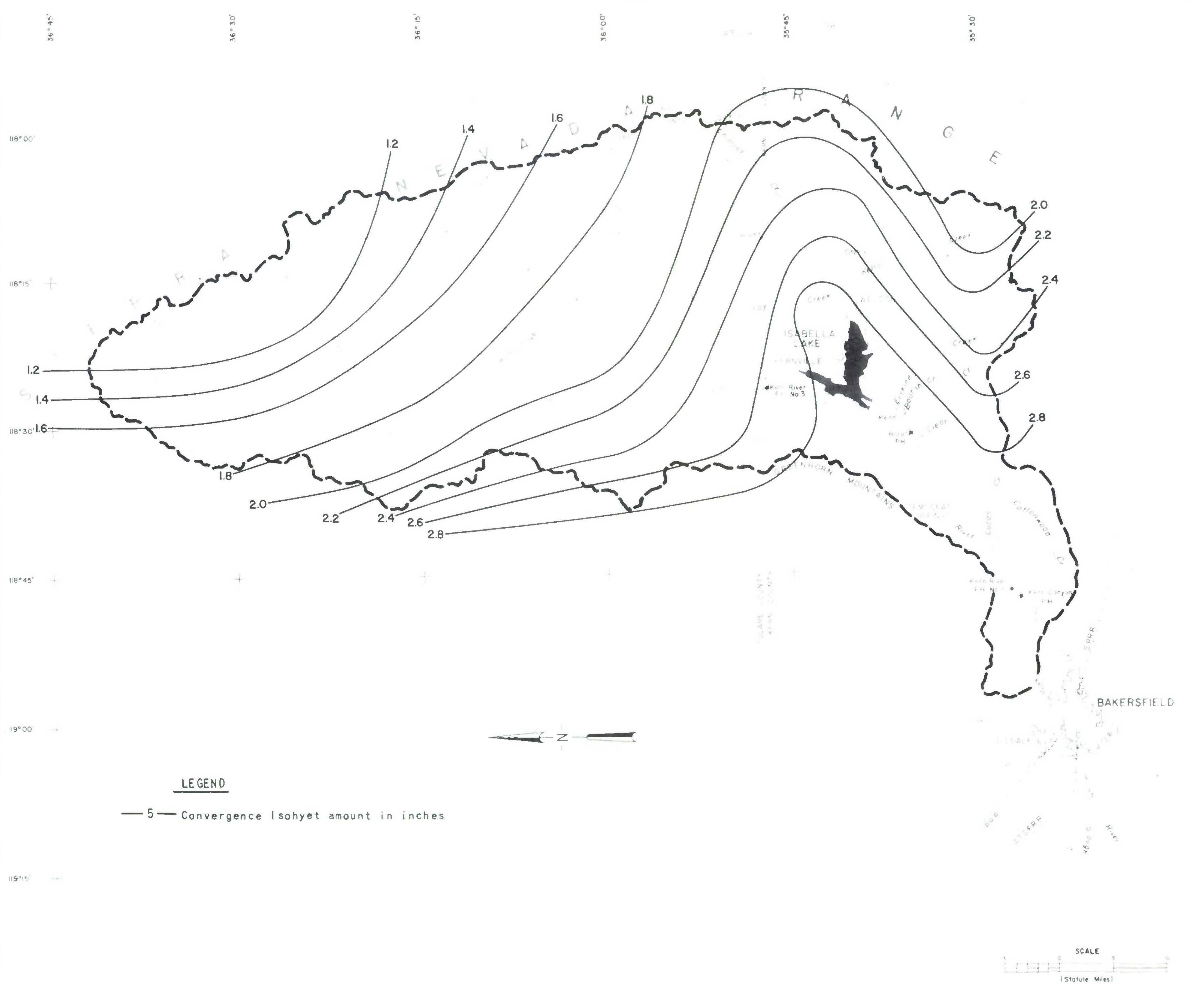
OROGRAPHIC
PROBABLE MAXIMUM PRECIP
INDEX
(6-HOUR)

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared RCK
Drawn CAP

Date JANUARY 1979

CHART 20



NOTE:

Indices based on U.S. Weather Bureau, Hydrometeor-logical Report No. 36, October 1961 with revisions of October 1969.

LEGEND

—5— Convergence Isohyet amount in inches

KERN RIVER, CALIFORNIA

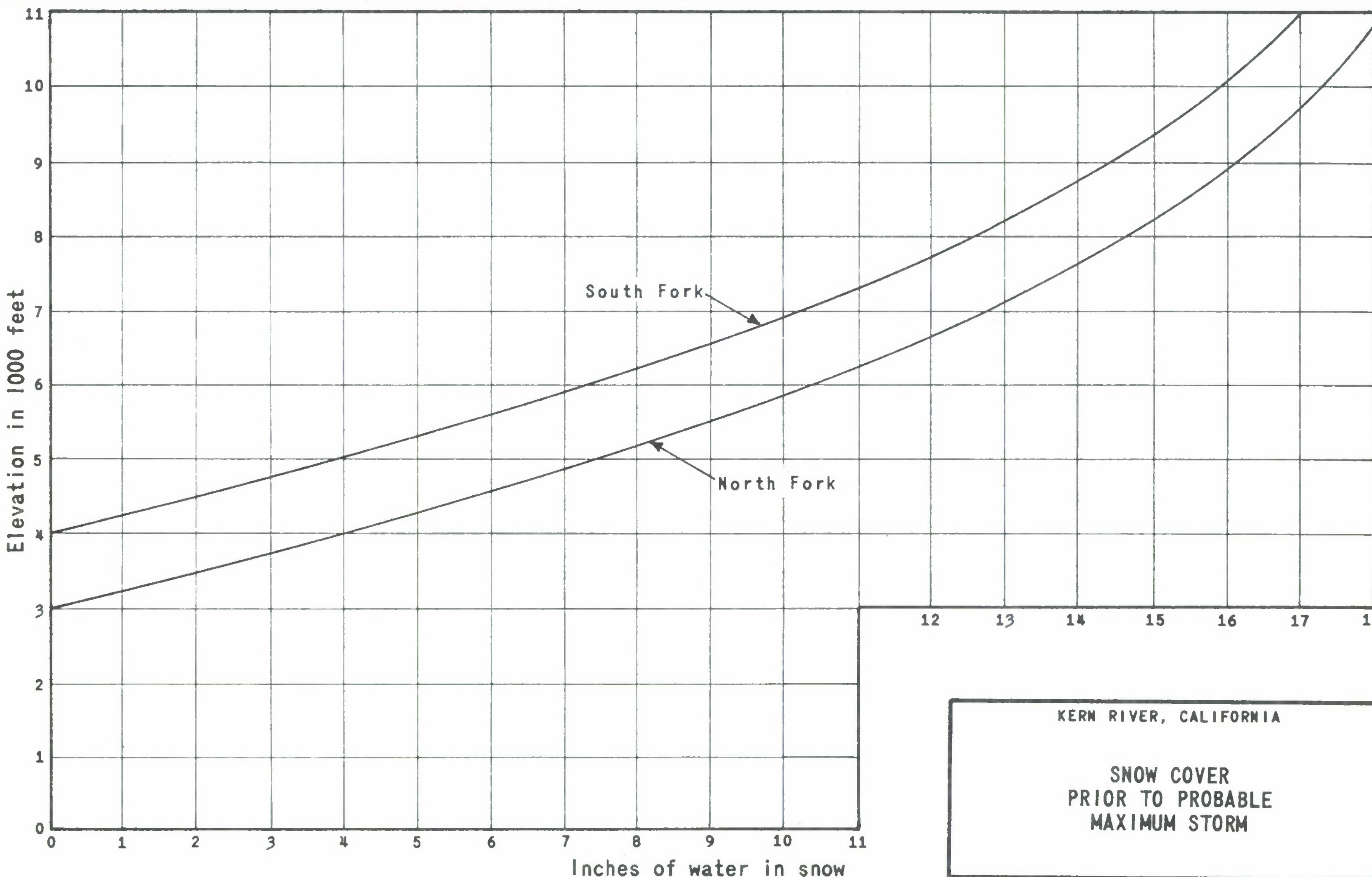
CONVERGENCE
PROBABLE MAXIMUM PRECIP
INDEX
(6-HOUR)

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.

Date: JANUARY 1979

CHART 21



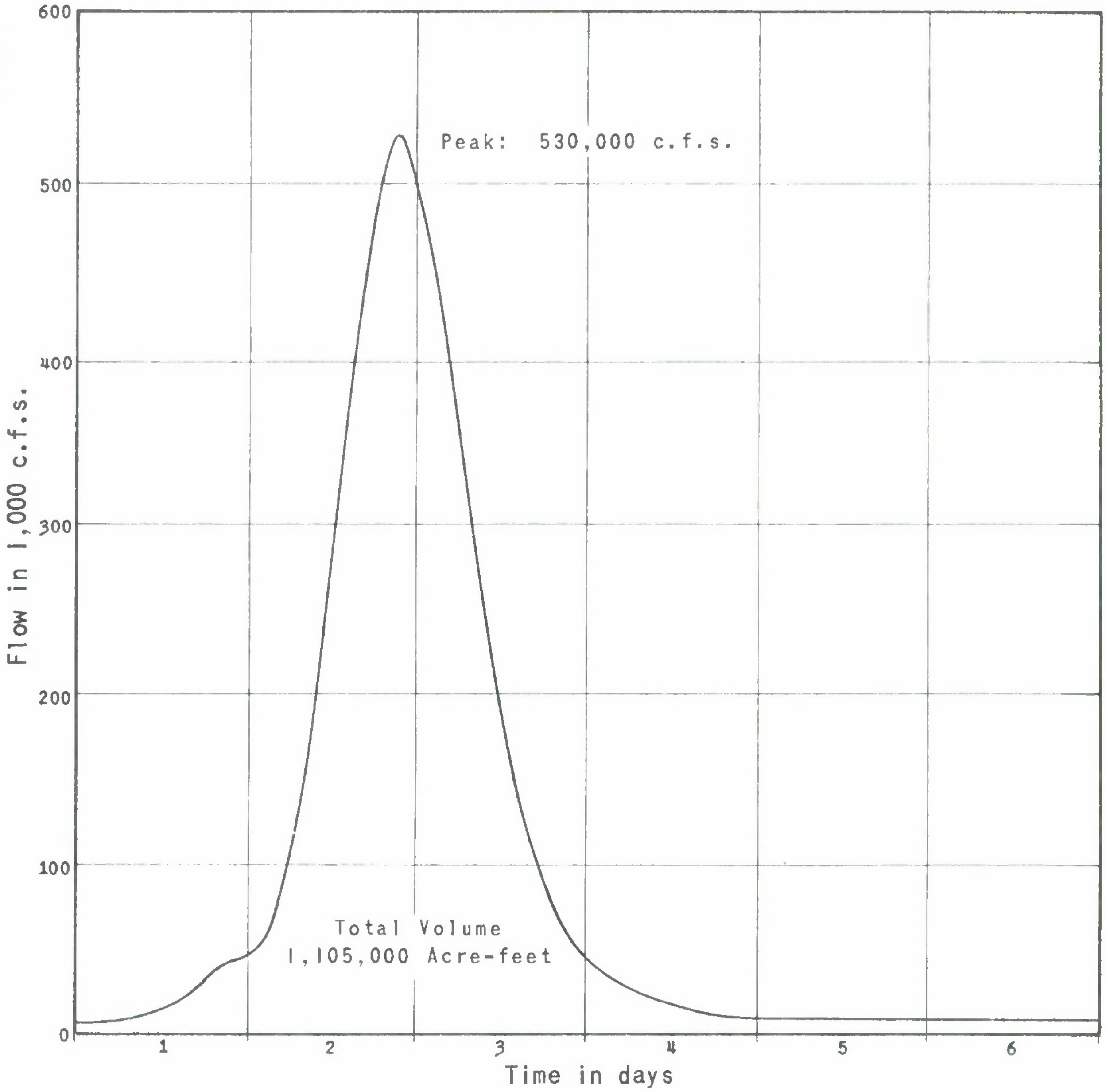
KERN RIVER, CALIFORNIA

SNOW COVER
PRIOR TO PROBABLE
MAXIMUM STORM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

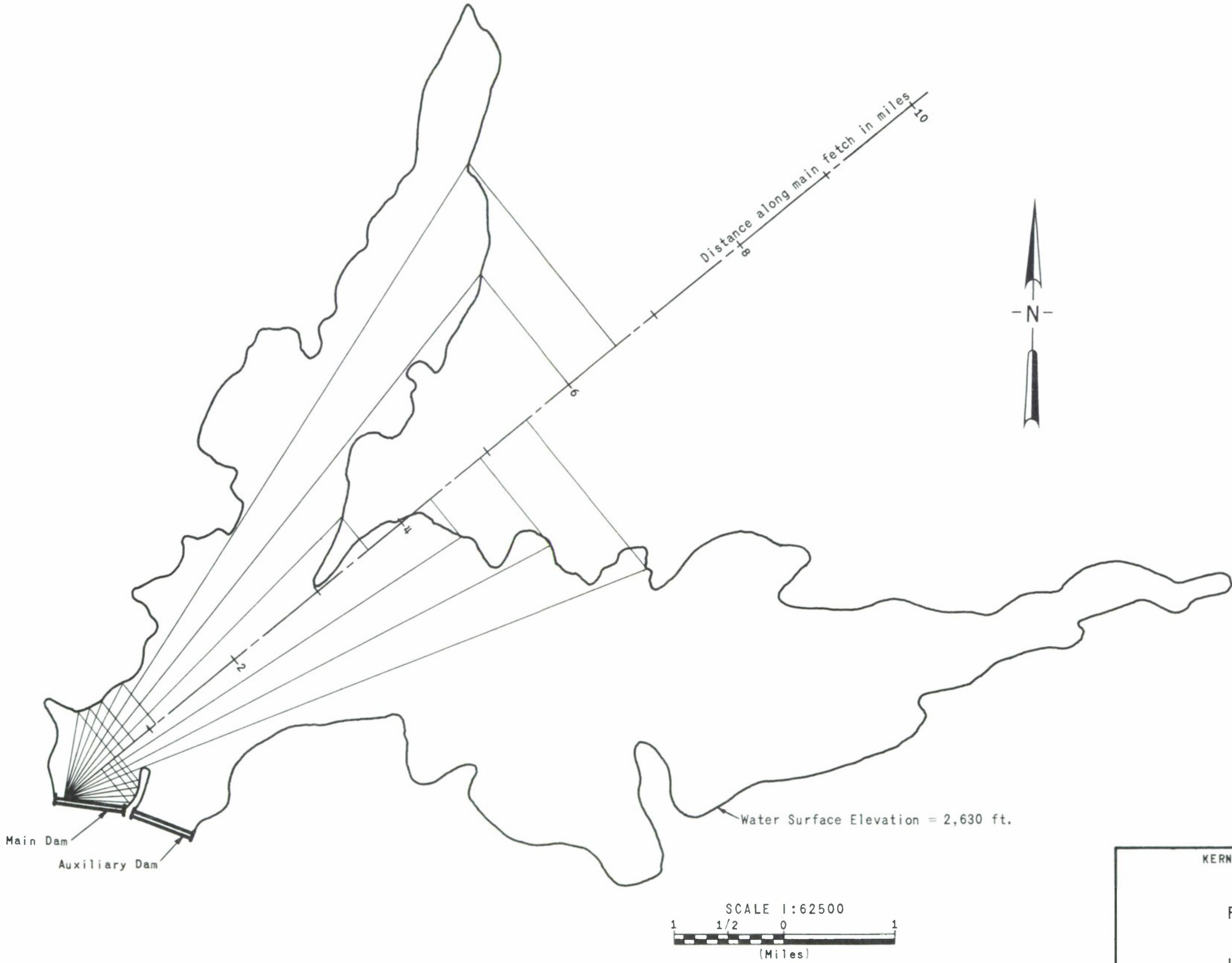
CHART 22



Contributing drainage area: 1,642 sq. mi.

KERN RIVER, CALIFORNIA PROBABLE MAXIMUM FLOOD HYDROGRAPH ISABELLA LAKE
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA
Prepared: R.C.K. Drawn: C.A.P. Date: JANUARY 1979

CHART 23



KERN RIVER, CALIFORNIA

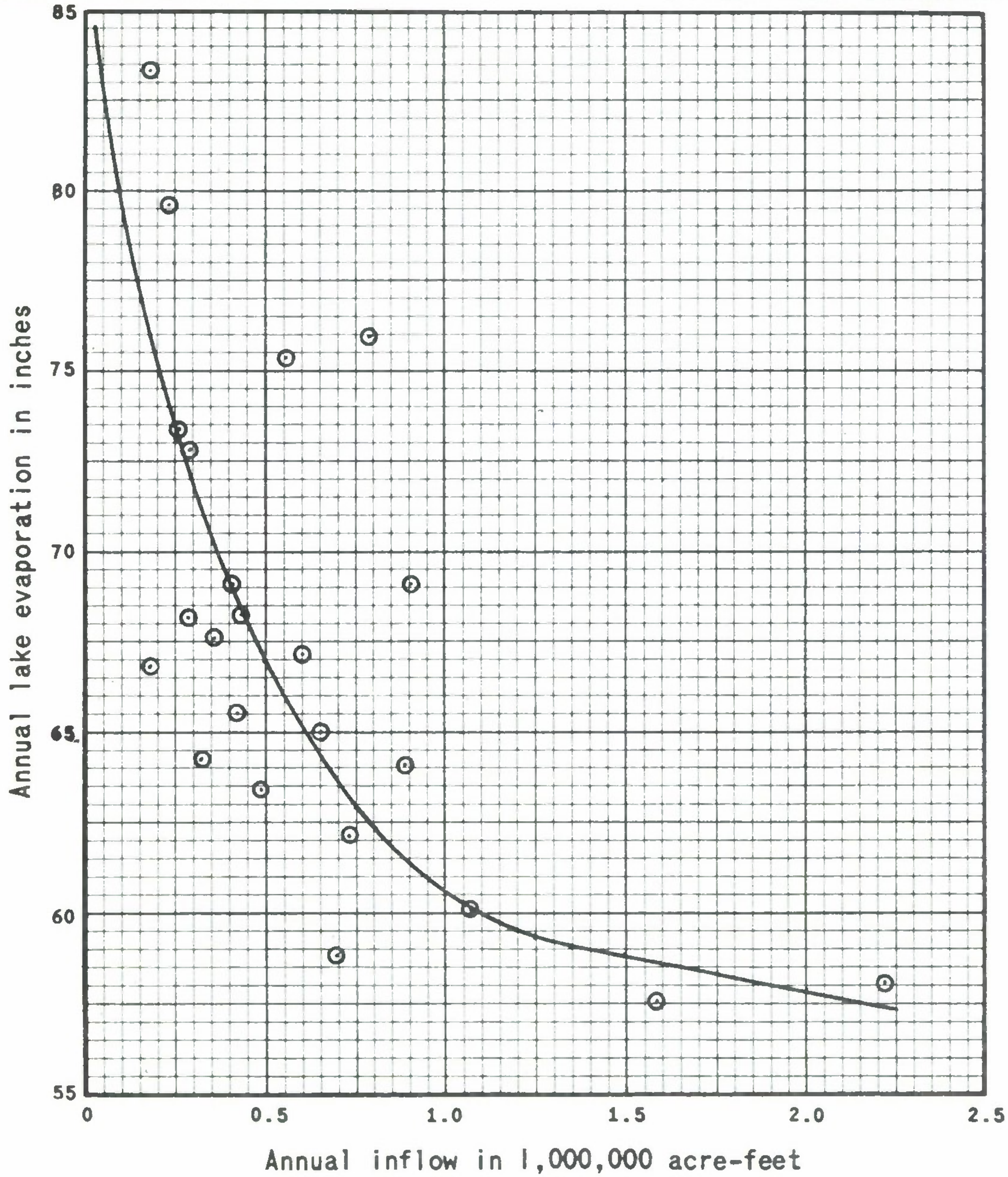
FETCH DIAGRAM

ISABELLA LAKE

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: C.A.P.
Drawn: C.A.P.
Date: JANUARY 1979

CHART 24



ANNUAL EVAPORATION AND INFLOW DATA		
WATER YEAR	COMPUTED ANNUAL EVAP. (inches)	ANNUAL INFLOW (1,000 ac. ft.)
1955	67.6	356
1956	64.1	870
1957	65.4	439
1958	60.0	1,058
1959	72.8	277
1960	68.2	279
1961	66.8	175
1962	65.0	654
1963	62.2	738
1964	64.3	323
1965	58.8	697
1966	69.0	400
1967	57.5	1,576
1968	63.4	489
1969	58.1	2,226
1970	67.2	604
1971	68.2	428
1972	73.4	257
1973	69.1	912
1974	76.0	788
1975	75.4	558
1976	79.6	238
1977	83.3	186
AVERAGE	67.6	632

KERN RIVER, CALIFORNIA

ISABELLA LAKE EVAPORATION

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.
Date: JANUARY 1979

TO: Defense Technical Information Center
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22 October 2008

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Sacramento CA 95814-2292

SUBJECT: Submission of technical reports for inclusion in Technical Reports Database

The enclosed documents from USACE Sacramento District are hereby submitted for inclusion in DTIC's technical reports database. The following is a list of documents included in this shipment:

ADB344304 • Lemon Reservoir Florida River, Colorado. Report on reservoir regulation for flood control, July 1974

ADB344333 • Reconnaissance report Sacramento Metropolitan Area, California, February 1989

ADB344346 New Hogan Dam and Lake, Calaveras River, California. Water Control Manual Appendix III to Master Water Control Manual San Joaquin River Basin, California, July 1983

ADB344307 • Special Flood Hazard Study Nephi, Utah, November 1998 (cataloged)

ADB344344 • Special Study on the Lower American River, California, Prepared for US Bureau of Reclamation – Mid Pacific Region and California Dept. of Water Resources..., March 1987

AD B344313 Transcript of public meeting Caliente Creek stream group investigation, California, held by, the Kern County Water Agency in Lamont, California, 9 July 1979

ADB344302 • Initial appraisal Sacramento River Flood control project (Glenn-Colusa), California, 10 February 1989

ADB344485 • Report on November-December 1950 floods Sacramento-San Joaquin river basins, California and Truckee, Carson, and Walker rivers, California and Nevada, March 1951

ADB344268 • Reexamination Little Dell Lake, Utah, February 1984

ADB344197 • Special report fish and wildlife plan Sacramento River bank protection project, California, first phase, July 1979

ADB344264 • Programmatic environmental impact statement/environmental impact report Sacramento River flood control system evaluation, phases II-V, May 1992

ADB344201 • Hydrology office report Kern river, California, January 1979

ADB344198 • Kern River – California aqueduct intertie, Kern county, California, environmental statement, February 1974

ADB344213 • Sacramento river Chico Landing to Red Bluff, California, bank protection project, final environmental statement, January 1975

ADB344265 • Cottonwood Creek, California, Information brochure on selected project plan, June 1982

ADB344261 • Sacramento river flood control project Colusa Trough Drainage Canal, California, office report, March 1993

ADB344343 • Detailed project report on Kern River-California aqueduct intertie, Kern County, California, February 1974

- ADB344267 Sacramento River Flood Control Project, California, Right Bank Yolo Bypass and Left Bank Cache Slough near Junction Yolo Bypass and Cache Slough, Levee construction, General Design, Supplement No. 1 to Design Memorandum #13, May 1986
- ADB344246 Redbank and Fancher Creeks, California, General Design Memorandum #1, February 1986
- ADB344260 Cache Creek Basin, California, Feasibility report and environmental statement for water resources development Lake and Yolo counties, California, February 1979
- ADB344199 Sacramento River Deep Water Ship channel, California, Feasibility report and environmental impact statement for navigation and related purposes, July 1980
- ADB344263 Sacramento River flood control project, California, Mid-Valley area, phase III, Design Memorandum, Vol. I or II, June 1986
- ADB344262 Marysville Lake, Yuba River, California, General Design Memorandum Phase I, Plan Formulation, Preliminary Report, Appendixes A-N, Design Memorandum #3, March 1977

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The Sacramento District source code is **410637**. Please return any materials that aren't appropriate for the technical reports database.

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